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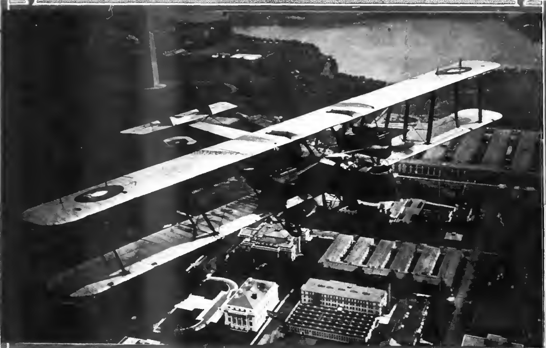

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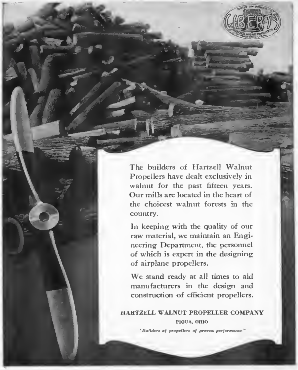

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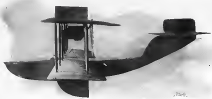

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Vol. VII September 1, 1919 No. 3

THE International Airplane Race and Handicap Contest organized by the American Flying Club, which ended just when AVIATION AND AERONAUTICAL ENGINEERING was going to press, afforded the American public the most inspiring aeronautical demonstration ever given. The number of contestants and the types of airplanes entered made of this race the most important event of its kind to date, but beside this purely spectacular element an important innovation was furnished by the handicap formula which constitutes the first attempt to find a scientific expression for comparing the efficiency of airplanes belonging to a wide variety of types

Owing to the fact that official figures on the outcome of the race are not available at the time of going to press discussion of its technical aspects has to be reserved; nevertheless the outstanding fact is that out of fifty-three actual starters, thirty-two, that is, over 60 per cent, finished the race within the set time limit. Of those eliminated by accidents four machines were totally crashed, but the remaining ships suffered only minor injuries which do not impair their future serviceability and—what is perhaps the most valuable lesson of the whole contest—only three airplanes were eliminated by engine trouble. This is truly a remarkable percentage if one considers that the race was run under most harrowing weather conditions and that the control stations were in many cases unfavorably situated with regard to the prevailing winds and of restricted area.

The New York-Toronto race was in particular a brilliant vindication of the Liberty engine, which propelled most of the big ships, although other engines showed up equally well, so that, altogether it may be said that American airplane engines have reached a point of perfection where they are second to none

Likewise, the competing airplanes, virtually all of American design and manufacture, put up performances which justify the greatest pride and performance in the ability of our engineers and constructors.

The American Flying Club, as the organizer, and the Air Service, whose cooperation assured the success of the race, deserve the most sincere congratulations of the aircraft industry for having given such a magnificent object lesson of the potentiality of aviation.

Gyroscopic Effects of the Propeller

A good deal of controversy has been carried on with regard to the gyroscopic effects of the propeller The gyroscopic forces have a bearing not only on the controllability of the plane, but also on propeller stresses, and on propeller bearing stresses. Some designers have used as their criterion extraordinarily rapid turns, and imposed excessive gyroscopic forces on their designs. Others have been inclined to neglect all consideration of these effects

A simple method of considering the problem, which would nevertheless coordinate it with the general structural strength of the airplane, is to consider the airplane at the moment when it is flattening out from a dive, at which time the dynamic forces are a maximum. Assuming the velocity to be known at such a point—and it will be very little below the limiting speed of the airplane—a simple dynamical equation will give the rate of turn And this rate of turn will furnish a very sound basis for computing the gyroscopic effects.

Inversion of Control Surfaces

In a recently published text-book of elementary aeronautics, there occur the following lines: "In case of a very steep or vertical bank, the functions of rudder and elevators are completely reversed: the rudder, being than in a horizontal position, will be used to bring the nose of the machine up or down the elevators being vertical serve to make the machine turn round In connection with steep banks, the terms used for the rudder are: top rudder and bottom rudder, irrespective of the fact that in either case it may be right or left rudder. For instance, if the machine is banked so that the right wing is down, then bottom rudder, in this case, would be equivalent to right rudder; but if the case is reversed, that is, if the machine is banked with the left way down, then bottom rudder would mean left rudder."

Now this is a perfectly correct statement of the case, and, what is more, the terminology is very widely accepted Everywhere we read of reversed action, or of inversion of control surfaces.

And yet in reality there never is reversed action, and the terminology is unnecessarily confusing

The difficulty arises from the fact that the earth and the vertical are considered as points of reference for the motion of the airplane, instead of the much more logical system of three axes at right angles to each other, passing through the center of gravity and rigidly fixed to the plane.

With such axes held in mind, the elevator on a steep or vertical bank is still performing its normal function of pitching the plane up and down about the athwartship axis, the rudder is still performing its normal function of turning the plane to left or right about an axis in the plane perpendicular to the athwartship and longitudinal axes Consequently there is no need for inversion of terminology

Airplane Engine Vibration

By Glenn D. Angle

One of the essential features of an airplane engine is smoothness of running. This is obviously true of any type of internal combustion engine; but the degree of unevenness allowable, in every case, depends mainly upon the rigidity and absorbing qualities of the engine mounting. Excessive engine vibration will produce unpleasant tremors throughout the entire structure of the lightly constructed airplane fuselage, and the effects therefrom may prove to be of a critical nature. The tendencies are to loosen joints and fittings and to crystallize metal parts, therefore an analysis for the purpose of reducing, if not altogether eliminating, vibration, will not be amiss. Since the engine is the principle offender, the engine designer is confronted with problems which should receive his strictest attention.

Before taking up the design problems involved, however, it will be well to consider the sources of vibration which are beyond the designers' control. Any deviation from normal functioning will introduce engine vibration in amounts which will, in a measure, correspond to the degree of this deviation. These vibrations are due to the so-called troubles which should be corrected by the mechanic or "trouble shooter" in the process of tuning up the engine.

Preignition is the most common source of trouble, and its effects may sometimes become very marked. It may be due to an early spark, local heating or high gas temperature attained during compression. High compression engines designed to work best at high altitudes will undoubtedly preignite if allowed to run with wide-open throttle on the ground, and it follows, if comparisons of various engines are to be made from tests as to their smoothness of running, that these tests should be conducted under atmospheric conditions encountered in flight.

Unequal forces of explosion in the cylinders produce torque variations of unequal magnitude, and consequently add to the vibrations already existing from that source. The explosive forces are not equal when the gas reaching each cylinder varies in mixture strength. If an engine has a correctly designed manifold giving an equal charge to each cylinder, variations of this nature are due to air leaks in the manifold, at the manifold flange or through a valve whose spring is weak, probably due to having its temper drawn by the extreme heat. Upon reaching the cylinders, the gas must be influenced by sparks of equal intensity following the full retention of the charge during the process of compression. Loss of compression by leaks past the piston rings is a common source of trouble. This can very easily occur if the rings are not properly fitted or are out of round or broken.

The variation of torque may be effected by changes in the interval of explosion as well as by its magnitude. If the sparks do not occur simultaneously, the charge is not ignited at the same period in each cylinder, and hence the explosion does not take place at the correct interval. This is due to uneven distances between the cams on the magneto breaker.

The fluttering of a propeller which is out of balance or too lightly constructed is transmitted through the crankshaft to the crankcase and engine beds. If the engine bed bolts are loose, the engine tends to lift itself and return to the bed at each revolution of the crankshaft. This hammering effect may reach quite appreciable magnitudes.

All apparent vibrations, not due to some of the troubles referred to above, are undoubtedly inherent with the particular type of engine under investigation. Since no practical device is yet known with which to accurately measure and record the amplitude of engine vibration, our only recourse is to treat such source by mathematical analyses and compare the results. Even though it were possible to measure these amplitudes, it would still be necessary to determine, by analytical means, which of the four principle sources had caused these vibratory proportions. In design, each source must be treated separately and the results obtained form a comparative basis of the vibratory tendencies existing in different types of engines and then enable the designer to apply the necessary remedy to those components which must withstand the greatest shock.

Vibration may be due to the springing and distortion of the material of which the engine is composed or to the unbalanced forces resulting from the motion and position of the components in respect to one another. A certain degree of yielding vibration exists in each component, but this does not become a disturbing factor unless its period is in step with multiples of other vibration periods, principally those due to power impulses. This is particularly true of the crankshaft and crankcase, which must withstand the reactions of engine torque.

The forces setting up vibration in the engine may be due to unbalanced rotating masses, unbalanced inertia of reciprocating parts or to torque reaction. It is difficult to estimate accurately the degree of vibration caused by the centrifugal forces or couples of unbalanced rotating masses, as this depends mainly upon the rigidity of that part of the case resisting these forces. Since rotary balance and crankshaft torsional vibration are general subjects and have been quite extensively covered in various engineering books, no special treatment is required in regard to any type of airplane engine as the principles involved are identical.

Attempts on the part of designers to develop engines more suitable for the propulsion of aircraft have led to various cylinder dispositions and generally to an increase in the number of cylinders employed. Unbalanced inertia and torque reactions are greatly effected by these changes, and, since our data ordinarily only applies to conventional engine types, it will be interesting to investigate into the possibilities and advantages of other designs. The treatments which follow, while as brief as possible, include practically all known engine types for purposes of comparison.

Unbalanced Inertia

The vibratory action of an airplane engine, in many instances, is due to the effects of unbalanced inertia. The selection of cylinder and crank arrangement should be made with a view of obtaining inertia balance whenever possible without seriously effecting many other equally important and essential features of the airplane engine. In a number of cases, however, it will be found that the reciprocating parts can be partially, or even completely, balanced without the least sacrifice to the features desired.

Owing to the accelerating and decelerating motion of the piston and the parts which move with it (including the upper portion of the connecting rod) there must exist forces to counteract their inertia. Energy is absorbed during the first part of the reciprocating motion and is given up during the latter part of the stroke; hence there is no resulting work from inertia, but the vibratory effects at certain parts of the cycle may become quite pronounced.

Before taking up the comparisons of three effects in various engine types let us consider the inertia forces in one cylinder. Due to the fixed path of the piston along the cylinder axis, the motion is not harmonic and can only be completely expressed by an infinite number of terms of a Fourier series. The values of these terms diverge so rapidly, however, that only the first two need be used to obtain results within all practical limits of engineering calculations. The formula is usually expressed as follows:

$$F_i = \frac{WV^2}{gR}\left(\cos + \frac{r}{l}\cos 2\theta\right) \text{ approximately}$$

F_i = Inertia force in lb

W = Weight of reciprocating parts in lb

V = Velocity of crank pin in feet per sec.

g = Gravity — 32.2

R = Crank radius in ft

r = Crank radius in in

l = Length of connecting rod in in

θ = Crank angle in degrees.

In order to obtain high engine speeds without shortening the life of the bearings it is very essential that the inertia forces be kept as low as possible. It can be readily seen in the above formula that these forces vary directly as the weight of the reciprocating parts and as the square of the crankpin velocity. The weight of the reciprocating parts must consequently be reduced to the minimum allowable in order to obtain the highest engine speeds. Some of the present aluminum piston constructions are interesting examples of advances in this direction.

The inertia forces can only be completely balanced by equal inertia forces acting in the opposite direction. The primary inertia force, that is, harmonic motion or that part of the force represented by the formula having only the first term in the bracket included, can be balanced by a rotating part of the same weight at the crankpin radius. This is accomplished, however, only at the expense of introducing an equal force in a plane at right angles to the cylinder axis. It is for this reason, in one cylinder engines, that an attempt is only made to balance half of the primary inertia force and thereby keep the unbalanced forces the smallest possible in all directions. The secondary inertia force, represented by the formula, having only the second term in the bracket included, can only be balanced similarly by rotating masses at twice crank speed. The same is obviously true of the remaining terms of this series providing the masses were rotated at a speed corresponding to their respective phases. As explained above, these terms are not of great importance, hence only the magnitudes and phases of the primary and secondary inertia forces, and in relation to their resultant or total inertia force, are shown on Fig 1 for comparison. The values were obtained by assuming that the reciprocating parts weigh 3 lb and that the crank revolutions are 2000 per min.

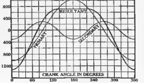

Fig 1 Primary and Secondary Inertia Forces

In order to keep the investigations which follow within practical limits and in a condensed form, no regard is taken of the higher harmonics having greater periodicity and comparatively lower magnitudes. The values used were obtained by use of the formula given above. Separate consideration of the primary and secondary forces has been avoided as much as possible, since it is intended to investigate, in the various engine types, the inertia balance regardless by which of the harmonics it is being disturbed. The reader can always bear in mind to what extent it is possible to balance the inertia forces by rotating masses, but as this is not complete, adds weight, and in most cases is not practical, it is readily understood that the best method for obtaining inertia balance is to arrange the cylinders properly in relation to one another.

One Cylinder Engines

It has been explained above that the inertia forces can only be completely balanced by equal forces acting in the opposite direction, hence, the conventional type of single-cylinder engine represents an impossible problem in perfect inertia balance. Some very novel arrangements have been devised whereby the forces in an individual cylinder are perfectly balanced by employing two pistons, or in reality making two cylinders into one. One of the early types of aviation engines, the Gobron-Brillé, is an extremely interesting example of this kind. In addition to the ordinary crank, rod and piston construction, a piston is operated in a reverse direction to the main piston motion by means of a crosspiece hinged to two connecting rods which are outside the cylinder, and on crankpins symmetrically disposed at 108 deg to the main crankpin.

A more recent type has been brought out by Prof Junkers of Aachen, Germany. Very little data is available on this engine, but the principle involved is practically identical to some of the heavier types of engines constructed by him. Two crankshafts employed at the opposite ends of a single combustion chamber are driven from the explosions, which act upon two pistons having the same relative motion described above. It is veritably two single cylinder engines having the heads so joined as to give a single combustion space. Incidentally, aside from obtaining perfect inertia balance, there are other equally important advantages to be had by this arrangement.

Two-Cylinder Engines

The two-cylinder opposed engine, having cranks 180 deg apart, represents complete inertia balance by reason of the opposite direction of piston motion. The cylinders may be located on the same center line with two symmetrical cranks for one of the cylinders, or slightly offset with individual cranks. In the latter case, however, it must be remembered that a couple is introduced at right angles to the crank center-line.

All other two-cylinder arrangements are out of balance in respect to reciprocating inertia. The detrimental effects of these unbalanced forces are generally eliminated by balancing the primary or simple harmonic forces with rotating counterweights properly located on the crank. The tandem arrangement of two cylinders, with cranks located 180 deg apart, is of most interest, as it is actually one-half of a conventional four-cylinder engine. The resulting unbalanced force is along the axis of the cylinder and has one-half the magnitude of the four. This is taken up next, and suitably explains the resulting unbalanced inertia forces of an engine having two cylinders arranged in tandem.

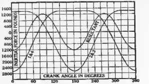

Fig 2 Four-Cylinder Unbalanced Inertia Forces

Four-Cylinder Engines

Since pistons number one and four are in phase, and are out of phase with pistons number two and three by 180 deg, it only requires two curves of twice the magnitude of one cylinder to represent these forces for the conventional four cylinder arrangement. The curves and the resultant are shown on Fig 2. It is quite evident from the magnitude of the resulting forces that these may become disturbing factors. Since the resultant curve represents the unbalanced inertia force of four cylinders in axial directions, it can be used to determine the unbalanced components of engines composed of multiples of four-in-line cylinders.

A four-cylinder Vee type arrangement which has been recently presented is known as the W B B Aero Motor. Just as the two-cylinder in-line engine is one-half of a four, so is this engine as compared to an eight-cylinder Vee type. The inertia balance is similar to the eight-cylinder Vee engine, but the forces in each bank of cylinders are of only half the magnitude.

Eight-Cylinder In-Line Engines

In the course of engine development during the war there was introduced eight-cylinder in-line engines which had two four-cylinder crankshafts attached at ends with axes 90 deg apart. This crank arrangement gives even intervals of explosion. The Bugatti, a French design, was the best known of this type. The Germans had the 240 hp Mercedes, which was

identical in construction to the 160 hp., six-cylinder Mercedes engine, but with an additional two cylinders It is not believed that many of these engines were used, as very few were captured, and during the latter part of the war they were considered obsolete.

The inertia balance of this type is easily obtained by referring to the curves given for the four-cylinder engine. By placing two resultant curves 90 deg apart, this being the relation of the crank axes, it will be found that the algebraic sum of their values at any point is zero In reference to the transverse plane, the engine is therefore balanced in respect to inertia. The usual rocking couples along the longitudinal axis are present, however, as in any four-cylinder arrangement, but out of phase with each other by 90 deg.

A sixteen-cylinder Bugatti engine was constructed by placing two eight-cylinder blocks vertically side by side on one crankcase Since two crankshafts were employed the inertia balance of either row of cylinders was not altered This engine was duplicated in this country and known as the King Bugatti The principal advantage of this arrangement is obtaining available space between the two rows of cylinders in which to mount a cannon.

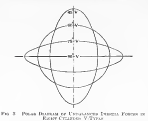

FIG 3 POLAR DIAGRAM OF UNBALANCED INERTIA FORCES IN EIGHT CYLINDER V-TYPES

Eight-Cylinder Vee-Type Engines

The eight-cylinder Vee type engine is virtually two four-cylinder in-line engines operating on a single crankshaft. The angle at which these two banks of cylinders are placed on the crankcase in respect to one another is influenced by certain factors in design. Low head resistance in the airplane is desirable, therefore the cylinders can be arranged so that the fuselage cowling which incloses them will have a small projected area. Even intervals of explosion is advantageous, but can be dispensed with without detrimental effects if the gain in low head resistance warrants it.

The most common, or we may say conventional, angle of Vee for eight-cylinder engines is 90 deg This arrangement gives even intervals of explosion, that is, explosions every 90 deg of crank movement. It also leaves sufficient room between the cylinder banks in which to mount carburetors and manifolds quite easily The Curtiss OX and the Hispano-Suiza engines are representative of many well-known units constructed in this manner

As each bank of four cylinders has its respective unbalanced inertia, it is interesting to note the effects on the magnitude and direction of the resulting unbalanced forces from changes in the angle of the Vee A polar diagram made by resolving graphical representations of the forces along each cylinder axis, at certain crank intervals, will best show these effects.

Consider first the conventional 90 deg Vee engine The horizontal line, shown on Fig 3, signifies that these forces are continuously acting in a horizontal plane and are of comparatively large magnitudes. The vibratory effects of these unbalanced forces are quite noticeable when the engine is mounted in a fuselage These vibrations are generally considered quite objectionable.

Suppose even firing is dispensed with by decreasing the angle of Vee to 75 deg The unbalanced component along the horizontal is somewhat diminished, but not to the amount of that introduced in the vertical plane. Narrowing up the cylinder banks obviously lessens the horizontal component of inertia so that at 60 deg we find the component the same in any one direction, and therefore the smallest when considered in all directions. The Packard Co have very recently brought out an engine of this type which, considered from the standpoint of unbalanced inertia, is a suitable arrangement The first Liberty engine had eight cylinders, with 45 deg as the included angle of Vee Although the horizontal component of inertia of this type is still further decreased, the vertical component becomes as large as the horizontal in the 90 deg Vee type, therefore nothing is to be gained by reducing beyond a 60 deg angle unless it is possible to reduce the head resistance perceptibly as a result of the narrower engine

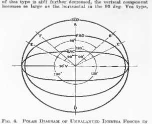

FIG. 4. POLAR DIAGRAM OF UNBALANCED INERTIA FORCES IN TWELVE-CYLINDER V-TYPES

Sixteen-Cylinder V-Type

The best-known sixteen-cylinder "V" type engine is the Model H Duesenberg, having two banks of eight cylinders with 45 deg as the included angle. The length of this engine approaches prohibitive dimensions for use in an airplane, but should be in favor for dirigibles. Since each bank of eight cylinders are in balance, it follows that the same is true for both.

Twelve-Cylinder W-Type Engines

The addition of a third bank of four cylinders gives a twelve-cylinder engine of approximately the same overall length as would one having four or eight cylinders. This is advantageous from the plane design standpoint, and the weight per horsepower should undoubtedly be less than a number of other twelve cylinder types, but there are serious objections to this arrangement, namely, added head resistance and poor inertia balance On Fig 4 are shown unbalanced inertia polar diagrams for some of these types in direct comparison with that of a 90 deg Vee eight-cylinder engine of the same cylinder size

Arranging the banks of four cylinders 60 deg apart in each Vee gives even intervals of explosion and presents a fairly compact design. An English engine, the Napier "Lion," and a French engine, the Lorraine-Dietrich, are of this type By referring to the diagram it will be readily seen, from *EAC* representing this cylinder arrangement, that the unbalanced inertia forces are greater in the horizontal than in the 90 deg Vee eight and in the vertical approximately those of a 75 deg Vee eight. This type of engine undoubtedly has excessive vibratory tendencies due to its poor inertia balance.

An experimental French engine, the Adabel, is virtually a conventional 90 deg Vee eight with an additional bank of four cylinders extending vertically downward. *FRD* on the diagram signifies that, while the horizontal component is equal to the 90 deg Vee eight, there has been introduced a vertical component of greater magnitude than that of a 90 deg Vee eight. This is actually the vertical unbalanced component of the lower four cylinders, therefore we have in this arrangement the combined unbalanced inertia of two well-known engines

Suppose the three banks of four cylinders were evenly spaced, that is, 120 deg apart. Reversing the direction of one four-cylinder unbalanced component from the first arrangement described by changing the position of one set of cylinders from *A* to *D* produces a vertical unbalanced component as great as the horizontal The polar diagram, shown as *ECD*, is a circle It is evident that the inertia forces cannot be balanced in twelve cylinder engines composed of three rows of four and unbalanced components are introduced in excess of corresponding eight cylinder Vee types.

Three-Cylinder Engines

One of the earlier airplane engines constructed by Anzani had three cylinders arranged fan shape with 72 deg as included angles. Fear of over lubrication in the lower cylinders was probably the reason for this peculiar disposition. The engine only developed about 25 hp and was poorly balanced for inertia. Our interest is mainly historic as it propelled the first heavier than air craft to fly cross the English Channel. Later Anzani built Y types in which the cylinders were located 120 deg apart. The inertia balance of this type will be found under the treatment of radial engines.

Three cylinders, arranged in line and employing three crankpins 120 deg. apart, are in perfect inertia balance, but owing to their respective lines of action being separated, there is introduced a rocking couple This can only be eliminated by an additional three cylinders in line providing the crank arrangement is symmetrical.

Six-Cylinder Engines

It is quite generally known that there are no resultant unbalanced inertia forces in the conventional six cylinder engine, but in order to make this point clear Fig 5 is given Three curves, each one representing the inertia forces in the cylinders whose pistons are in phase, are plotted 120 deg apart. The algebraic sum at any instant is zero

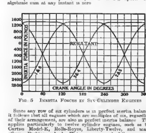

FIG. 5 INERTIA FORCES IN SIX-CYLINDER ENGINES

Since any row of six cylinders is in perfect inertia balance, it follows that all engines which are multiples of six, regardless of their arrangement, are also in perfect inertia balance This applies particularly to twelve cylinder engines, such as the Curtiss Model-K, Rolls-Royce, Liberty-Twelve, and many others. Eighteen cylinder W-types, composed of three rows of six, are not common, but should be in favor for units of higher power output A Sunbeam engine is probably the best known of this type

Radial Engines

The radial engine type, having a fixed star shaped arrangement of cylinders and a revolving crankshaft, presents an interesting problem of inertia balance The diagrams represent the resultant inertia forces of various numbers of cylinders

arranged radially The inertia force values for all cylinders were obtained by use of the formula at the proper crank angle, laid off along each cylinder axis in respect to magnitude and direction and resolved

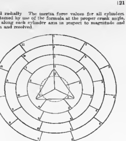

FIG 6 DIAGRAM OF RESULTANT INERTIA FORCES IN RADIAL ENGINES

It is interesting to note that in all but one case, the resultant diagram is practically a circle. At any instant the resultant unbalanced inertia is in the direction of the crankpin from the crankshaft axis, therefore it travels about center at crank speed having the same direction as the inertia force of any one cylinder when it is greatest, namely, at in or out center piston position Since the resultant force for the various odd numbers of radial engine cylinders is practically constant during one revolution, a direct comparison may be made with the inertia force of one cylinder with which it corresponds in direction. This will be taken at in center position, that is, when the piston is at the top of its stroke and farthest away from the crank axis. The radius of the dotted circle at the center is a measure of the magnitude of the inertia force of one cylinder at 0 crank angle

The resultant primary and secondary inertia forces are sometimes considered individually In all strictness it is the resultant of the primary inertia forces which travels at crank speed and at any instant is in the direction of the inertia force of one cylinder whose piston is at in center position Some designers only attempt to balance the resultant of the primary forces, neglecting the secondary as these are generally considered as being of little importance The secondary resultant incidently travels about center, but at twice crank speed

The cylinders in one plane and evenly located about a single crank pin must be odd in number in order to obtain equal intervals of firing The diagram represents the disposition of cylinders which number three to eleven inclusive, the latter being the greatest number it has been found possible to mount on a crankcase without producing prohibitive overall diameters from the standpoint of head resistance to the airplane. It is sometimes better to employ two groups of odd numbers of cylinders located in two planes and operating about a two-throw crankshaft, which has crank pins 180 deg apart The inertia balance of this type follows the treatment for the single plane of cylinders

As previously stated, a direct comparison can be made between the resultant unbalanced inertia of any odd number of cylinders in one plane and the inertia force of one cylinder at in center position. The diagram shows this clearly and may be scaled to obtain the ratio, but more accuracy will result if reference is made to the table given below These ratios are subject to slight variation with different crank throw and connecting rod lengths. The ratio $\frac{r}{l}$ in this case has been taken at .3 which approximates average airplane engine practice. The ratios of the resultant primary to the primary inertia is

also given for comparison. In every case this ratio is equal to one-half the number of cylinders.

Number of Cylinders	Ratio—Resultant Inertia Inertia Force of One Cylinder	Ratio—Resultant Primary Primary Inertia of One Cylinder
3	1.800	1.5
5	1.925	2.5
7	2.680	3.5
9	3.480	4.5
11	4.240	5.5

The resultant unbalanced inertia force can be balanced almost perfectly by the centrifugal force created by a mass properly located diametrically opposite the crankpin. The counterweight employed incidentally should also include the mass necessary to place the rotating parts in balance. To determine the mass necessary for inertia balance, substitute in the simple centrifugal force formula ($F = \frac{W v^2}{gR}$) a value for F equal to the product of the proper ratio as given above and F_i (the inertia force of one cylinder) taken at 0 crank angle. If the center of gravity of the mass employed for balancing is located at the crankpin radius the symbols in the above formula represent the same quantities as in the inertia force formula. However, if for any reason the location of this point is changed the values for R and v^2 should be altered accordingly.

Since the balance weights required become greater as more cylinders are employed in the same plane, some designers consider it better practice to locate the cylinders in two planes. In this arrangement the forces set up in the plane of one set of cylinders, namely the resultant inertia force, and the centrifugal force of the rotating masses, are balanced by corresponding forces in the plane of the second set of cylinders. This, however, is only in respect to a plane at right angles with the cylinder axis, due to the diametrically opposite positions of the crankpins. If no counter weights are employed to balance the forces in each plane of cylinders individually, couples are introduced which have a tendency to set up vibration. Since the reaction of the couple is resisted through the main crankshaft bearings the vibrations are limited mainly by the degree of crankcase rigidity.

A somewhat unconventional radial type is found in the Smith fixed radial engine which has ten cylinders in one plane, a two throw crankshaft and connecting rods whose axis are at an angle to the plane of the cylinders. This is virtually two five cylinder radial groups located in one plane and balanced in the manner described above as no counterweights are used. The advantage over a nine cylinder radial of the same size, is the additional power of one cylinder and a weight difference equal only to that represented by one more cylinder and a two throw crankshaft less the weight of the counter balance required for a nine. The couple set up, however, is in excess of that in a two plane ten cylinder engine due to the components of the offset rod action.

It will be noted from the diagram that the unbalanced inertia force of the three cylinder radial engine is represented by a triangular shaped figure. Obviously this type cannot be perfectly balanced. The unbalanced force at any instant is the difference in magnitude between the figure as given and that of a centrifugal force produced by a counterweight. In any event the force is too small to produce vibration of any appreciable magnitude. One of the recent three cylinder radials is the Lawrance 50 hp. engine which is of very commendable design.

Six cylinder radials, composed of two rows of three, should be in favor for light units developing around one hundred horsepower. The balance of this type is somewhat better than that of the three cylinder. This can be easily studied by placing two diagrams on the same center but with cylinder axes 180 deg. apart.

Rotary Engines

Since no simple reciprocating piston motion is represented in the rotary engine, with its fixed crankshaft, and rotating cylinder and pistons, there are no inertia forces to be considered. The cylinders rotate around the crank axis and the pistons are virtually swinging at the ends of the connecting rods about the crankpin center. All are in perfect balance as long as the weights of all rotating parts are kept uniform.

Report of Aviation Mission

Concentration of the air activities of the United States—military, naval, and civilian—within the direction of a single Governmental agency created for the purpose, co-equal in importance with the Departments of War, Navy, and Commerce, is the recommendation of the American Air Mission, headed by Assistant Secretary of War Crowell, which returned on July 20 from Europe after an extensive study of European air establishments.

Recommend Air Department

The proposed Air Department would be charged with full responsibility for "placing and maintaining our country in the front rank among nations in the development and utilization of aircraft in the national security, and in the advancement of civil aerial transportation and communication arts."

The organization of the proposed Air Department would call for a civilian Secretary of Air, a member of the Cabinet, with a civilian Assistant Secretary of Air, and five or more chiefs of such sub-departments as civil aeronautics, military aeronautics, naval aeronautics, supply and research, finance, and the like, and an advisory Air Council, constituted by the Secretary of Air and including among others his assistant and the chiefs of the sub-departments.

The Mission's report shows that its opinions are advanced after conferences with the Air Ministries of Great Britain, France, and Italy, with ranking Army and Navy officers of all three nations, and with the foremost aircraft manufacturers of the principal Allied nations.

Future of Air Transport

Concerning commercial aviation, the Mission emphasizes the necessity of conserving the American aircraft industry built up during the war, "ninety per cent of which has been liquidated" since the armistice. Some definite Government policy is necessary to save and revitalize the remaining ten per cent for the development of aerial transportation for commercial purposes, that the Mission predicts will "become one of the great transportation mediums of the world and will continue to offer the fastest and most direct means of transportation known to civilization."

The stage is set, for the first time in the world's history, for a close international cooperation in the development of a great art at the very threshold of its commercial utility, the Mission declares, and the United States must sooner or later follow the leads of Great Britain, France, Italy, and Japan to set up a single authoritative point of contact for the conduct of all international aviation affairs, legal, operational, technical, and political.

Dominance of the Air

Future wars, declares the Mission, will undoubtedly open with great aerial activity far in advance of contact either upon land or sea, and victory cannot but incline to that belligerent able to first achieve and later maintain its supremacy in the air. Great Britain, the mission reports, has come "to consider the dominance of the air as at least of equal importance with that of the seas and is frankly and avowedly planning a definite policy of aerial development to that end."

The report of the Mission is signed by Benedict Crowell, Assistant Secretary of War; Howard E. Coffin, member of the Council of National Defense; Henry C. Mustin, Captain, U. S. Navy, who signed with reservations; Halsey Dunwoody, Colonel, U. S. Air Service; James A. Blair, jr., Lieutenant Colonel, General Staff, U. S. A.; George H. Houston, President, Wright-Martin Aeroplane Corp.; C. M. Keys, Vice-President, Curtiss Aeroplane and Motor Corp.; and S. S. Bradley, General Manager, Manufacturers' Aircraft Association.

In making the report public, Secretary of War Baker issued a statement emphasizing the thoroughness and value of the studies made with regard to the importance of aircraft and the essential dependence of the art for its development upon a sympathetic attitude in the Government. It is clear, Secretary Baker writes, that the ingenuity and ability of American engineers and inventors must be coordinated and our national effort freed from wastefulness and duplication. The Secretary did not, however, agree with the Mission that the solution lay in a single centralized Air Service.

Airship Engineering Progress in the United States*

By J. C. Hunsaker, Eng. D.
Commander, Construction Corps, U. S. Navy

The B class ships had envelopes made of doubled fabric, with the threads of the "bias ply" at 45 deg. to the threads of the other. The bias ply is necessary to prevent tearing, but is rather uncertain in strength. It does help to take shear, however. Recent experiments with a three-ply fabric of which the middle ply only is bias are more encouraging, and indicate that we shall abandon the doubled fabric.

The three-ply fabric presents a remarkable degree of resistance in weathering. The aluminum surface, which keeps down the heat, is quite heavy, and is placed over a heavy outer film of rubber. Even though this complete outer film and the first layer of cloth and rubber should be broken down by exposure, there would still be two plies of fabric, with a heavy coating of rubber left to retard the diffusion of the contained

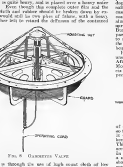

Fig. 8. Gammeter Valve

hydrogen. It is through the use of high count cloth of low weight and high strength that the successful three-ply fabric can be produced, and the Bureau of Construction and Repair has consistently stimulated the production of this type of cloth. It is probable that present researches will result in the production of both ballonet and outer envelope rubberized fabrics of lighter weight, greater strength and lower permeability than even those that are now in use. For instance, some experiments with rubberized silk fabrics show that these fabrics can be made exceedingly light in weight, high in strength, and of very low diffusion, and that these characteristics are maintained after exposure even for periods of over 150 days, provided sunlight is shut out by a good aluminum outer coating.

After balloon fabric has been in service for periods of from three months upward, changes may take place in the rubber compounds that are used for proofing that cause increased permeability to be shown. These results are more common in fabrics exposed under moist conditions, especially in hot climates where there is a maximum sunlight, and is generally observed on fabric that is over-vulcanized or that contains insufficient proofing.

In the early days of the war the British had considerable trouble with the fabric used in their airships, and finally decided to reduce the diffusion through the use of a cellulose coating known as Delta Dope. Very good results were obtained with this, and it was used to some extent. Later on, in view of the poor results that were obtained with early American airship fabric, a material similar to that which the British used was developed by the Bureau and used with success. This dope is different in its composition and action from that used for coating wings of airplanes. The latter material is used to shrink the cloth. Airship dopes contain a special form of cellulose nitrate of a higher degree of nitration, and are made soft and pliable by the addition of castor oil, which prevents the tautening effect when applied to fabric. These dopes when applied dry rather slowly and leave a film that is soft and highly resistant to the diffusion of hydrogen. It is customary to apply two coats of clear dope, and two or three coats of the same dope containing about 10 or 15 per cent of aluminum powder. For application of the dope, a portable spraying outfit of the extension rod type was obtained by the Bureau for air stations. It was found possible with this apparatus and a small crew of men to apply one coat of dope to a 85,000 cu. ft. envelope in one day. Because of this fact the operation of the airship was held up very little, the doping being done on rainy days.

Previous to doping, an airship at Rockaway had given very unsatisfactory results, showing a daily loss of 1.18 per cent. After doping, the daily loss was only .08 per cent hydrogen. Moreover, this airship continued in service for a period of six months after doping without showing high diffusion. Experience has shown that an airship which has a probable life

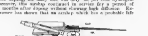

Fig. 9. Section of Gammeter Valve in Place

of only six weeks could by doping be put into service again so that it would have an additional life of at least six months. It was also found that the aluminum dope had a tendency to keep the gas in the envelopes at a more uniform temperature. This, of course, would make the ships much more stable on account of the lessened expansion and contraction of the gas. In another instance, a ship which had been in service for only a month undoped was giving unsatisfactory results and was showing a daily diffusion of 4.47 per cent. When the ship was doped by brush with three coats, a diffusion test showed a loss of only one-fifth of one per cent daily.

Leakage of Helium

To determine the comparative permeability of various fabrics to helium and hydrogen, the Bureau of Construction and Repair forwarded to the Bureau of Standards a quantity of helium and a number of fabrics of special construction, including rubberized fabrics such as are used for the envelope of non-rigid airships, and fabrics such as may be used for the gas bags of rigids. It was found that the helium permeability was from 59 to 64 per cent of that shown for hydrogen, and that a somewhat similar result was shown for the rigid fabric. The use of helium in airships of the future has been very much advertised, and the advantages of a non-inflammable gas are obvious. However, difficulties of supply render it necessary to devise ways to employ it with less loss than present hydrogen practices involve. The leakage through fabrics is less than with hydrogen, but the difference is not of great importance. The great bulk of gas now lost goes through the safety and maneuvering valves. It may be possible to rework helium that has become mixed with air. When the hydrogen in an envelope gets 20 per cent of air in it, it is explosive and is promptly discharged.

Researches have been made by the Bureau into the causes of mildewing which has been observed upon cordage and fabric shipped from France and stored in a warm place under humid conditions. Wherever the mildew is found the rope and

* Concluded from last issue

fabric have become rotted and unsafe. In the investigation, mildew spores were scraped from the surfaces and incubated on agar agar. The growths that were produced were identified as green pennicillium and blase aspergillus. Mold cultures were then used in treating samples of various kinds of fabric and hemp rope after the fabric and rope had been brush-coated with various chemicals which might have an inhibiting action upon the growth of the mold. It was found that a dilute solution of ammonium phosphate containing a small quantity of sodium benzoate, or a very dilute solution of bichloride of mercury, could be used with entirely satisfactory results. American practice is to coat both inside and outside surfaces of fabric with rubber so that mildew cannot attack the cotton. We also use wire cable for suspensions, and are therefore more concerned with rust than mildew on important members.

Parachutes

All airships as well as kite balloons are provided with parachutes to permit the crew to abandon ship in the air in case of fire. Fortunately there has not yet been occasion to use the parachutes except in practice. It is believed, however, that if a fire does start there is some danger of the parachute catching fire before it gets away clear.

Feeling that it would be desirable to render fire-resisting the silk that is used in the construction of parachutes, experiments were conducted with various salts, and it was found that impregnation with 10 per cent solution of ammonium phosphate gave successful results. The silk after treatment is dried and then formed into parachutes in the regular manner. The silk thus produced is resistant to flame, and when ignited ceases to burn almost instantly. Ageing tests have been made with cloth treated with ammonium phosphate and placed in an oven at high temperature for several days. These conditions failed to lower the strength of the fabric.

Suspension Systems

Practically all non-rigid airships which had been built up to the outbreak of the European war had what is known as a band suspension; that is, the lines carrying the weight of the car ran up to a band of strong, heavy fabric which extended in a continuous line around the envelope. This band was located so that the lines reached the band at about the points where they became tangent to the envelope. As no portion of the band could take a very great load, such a suspension meant that each line from the car had to be sub-divided again and again so as to distribute the load into the band at very close intervals. There was thus produced a very large number of small lines close to the envelope which greatly increased the power required to drive it through the air.

Early in the war the British Admiralty developed a much simpler and neater suspension, using the so-called Eta patch. An improved patch developed independently by the Goodyear Co. is used on all American airships.

In our suspension, steel wires are used, running up from the car to a patch on the envelope, which consists of four tapering "fingers" radiating from the point to which the suspension wire is attached. Each finger consists of a strip of fabric extending outward from a central portion from which two loops of manila rope project to receive the thimble of the suspension wire. Under each finger is cemented to the envelope an extension of one end of a loop, which has been frayed out and impregnated with rubber. Each end of the loop thus distributes its load into the envelope throughout the entire length of the finger, and the two loops having four ends give four fingers. This construction provides for a very wide distribution of the load from each suspension wire.

As a result of the use of the patch suspension, it has become possible to make the entire car suspension of steel wire cable, reducing the number and diameter of all suspension lines. This reduction in the amount of cordage in the neighborhood of the envelope has resulted in a considerable increase of speed.

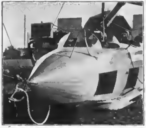

Fig. 10. Car of C-8, Showing Bow Suspension, Also Speed Indicator and Observation Windows

Fig. 11. Engine Mounting of C-8, Showing Air Scoop Behind Propeller and Parachute Carried in Car Bottom

Fins on airships constructed abroad are of the flat, externally braced type, in which the fin is stiffened by a series of king posts and wire struts, all on the outside of the fin and consequently giving a considerable amount of resistance. We introduced at the very beginning of our airship building a fin which is entirely internally braced, that is, its internal structure is such that it requires no external king posts or bracing wires. Naturally, this fin is considerably thicker than the European type of fin, but apparently is just as efficient as a control surface and weighs no more for unit area.

Valve Construction

Earlier valves on our non-rigid were of a most simple type of construction resembling the valves used abroad, and their tightness was nothing to be proud of. The problem of tight valves and certainty of operation was attacked by Mr. John Gammeter of the Goodrich Co., who produced an entirely original valve which it is believed has no superior.

The tightness of this valve is due to the lip packing which is carried by the cover of the valve, but when the valve is closed rests on a solid metal ring forming the frame of the valve. It extends toward the inside of the valve, gradually thinning to a knife edge, and is made of soft rubber. In consequence, when the pressure comes on the valve the tendency is for the

tip of this gasket or lip to press more and more firmly against the metal seat as the gas pressure increases.

The ideal valve for an airship should remain tight until the pressure at which it is to open has been reached, and it should then open wide and remain so until the pressure has decreased below the point at which it should open, whereupon it should close tightly. This valve very nearly meets these requirements. The arrangement of the linkage which carries the valve cover is such that the extension of the springs required to allow the full opening of the valve is very small. Consequently, the tension in the spring remains very nearly constant, and the ideal is very closely approximated.

In the first ships constructed by the Goodyear Co., the operation of the safety valves was controlled by a cord which extended across the diameter of the envelope, attaching together two valves, one on each side of the envelope. The theory was that when the pressure reached a certain amount, the sides of the envelope would be forced apart to a sufficient extent to produce a pull in the cord, causing the valves each to open and to remain open until the pressure fell sufficiently to allow them to close. The system works very well, but is difficult to keep in adjustment.

Fig. 12. Rescue of an Aviator from a Disabled Seaplane

Present valves depend entirely upon internal pressure for their operation, and open outward like a pop safety valve. All valves may also be operated manually. The present approved arrangement of valves is to have one at about the mid-length of each side and one at the tail of the envelope clear of the fins. The two side valves act as safety valves and are used for maneuvering only when both engines are stopped and a free balloon landing is necessary. The tail valve is the maneuvering valve for use under ordinary circumstances, so that the escaping hydrogen is well clear of fire from the engines.

C Class Airships

After the completion of the B class ships, there was an almost complete stop to airship work in the United States, and an improved single engine type which was designed in the winter of 1917-18 was not built. The reason for this was a discouraging report from abroad as to the effectiveness of airships on anti-submarine patrols. But the conclusions drawn from airship operations abroad in the bad winter weather proved to be premature, and as the good weather of the spring of 1918 permitted English and French airships to operate more freely, it became apparent that we should proceed immediately with a larger and faster type. Using this time all of the practical experience gained at home with B class ships and detailed information from abroad with regard to British, French and Italian airships, the Bureau of Construction and Repair undertook to take a step in advance and to design a ship of maximum performance. Full use was made of all available sources of information. In the initial stages of the design, the data regarding the performance of British airships, obtained from the British Admiralty through Lt.-Comdr. P. L. Teed, R. N. V. R.—attached to the office of the British Naval Attache at Washington—was especially helpful.

Experience showed the advantages of high speed to cope with winds, great endurance to follow convoys long distances, and a duplicated power plant to lessen chances of complete breakdown at sea. The C class was designed with these ends in view.

To obtain high speed, a new form of envelope and a car of very low resistance were developed from wind tunnel experiments. The speed was to be obtained by a combination of

Fig. 13. Bow of C Class, Stiffened by Wood Battens

high power with the utmost refinement in design to keep down resistance. Twin engines were used, giving a total of 250 h.hp. The actual speed on trial was 60 m.p.hr., making probably the fastest airship of its size ever built.

The principal dimensions and characteristics of the C-5, as weighed off before her start for Newfoundland, were as follows:

Length				192 ft.
Diameter				41 ft. 9 in.
Volume				182 000 cu. ft.
Purity	96.0 per cent.	Total lift		12 700 lb.
Temperature	65 deg. Fahr.			
Barometer	30 in.			
Weight empty				7 940 lb.
Weight carried,				
Crew (9) men			1,015 lb.	
Fuel			3,250 lb.	
Oil			120 lb.	
Navigating Equipment			25 lb.	
Radio			250 lb.	
Food			15 lb.	
Water for drinking			85 lb.	
Ballast			0 lb.	
Useful load				4 760 lb.
Endurance at 45 mi. per hr. 47 hr. or				2 130 mi.
Endurance at 55 mi. per hr. 28 hr. or				1,540 mi.

During 1918 contracts were placed with Goodyear and Goodrich for thirty airships, the cars to be supplied from the Burgess Co., Marblehead, Mass. After the armistice contracts were reduced to fifteen ships.

C-1, the first ship, was completed in Sept., 1918, and on Oct. 22, 1918, flew 400 mi. from Akron to Washington in 8¾ hr. It flew over the Navy Department building and landed at Anacostia to permit an inspection by officers of the department. It then proceeded to Rockaway, Long Island. Later in the year, the C-1 was ordered to Key West and flew down the coast, stopping at intermediate air stations.

The C-5 on May 14, 1919, flew from Montauk to Newfoundland with 6 men in 25 hr 50 min, a distance of 1022 naut mi. on chart, without stop. This flight will remain for a long time as a notable achievement. The distance actually flown (not being in a straight line) was about 1200 naut mi., or very nearly the distance from Newfoundland to the Azores.

The C-5 was unfortunately lost at Newfoundland in a gale while moored out in a field, and was, therefore, unable to attempt the trans-Atlantic flight, which was within her designed endurance.

The power plant of the C-1 consists of two Hispano-Suiza engines fitted with propellers to hold the engine down to 126 b.hp. This is done to increase reliability and because the envelope pressure is not sufficient for speeds over 60 m.p.hr. The C-5 had two Union 120 b.hp. engines. Each engine has an electric self-starter and the usual equipment.

The tanks are arranged in the rear of the car under the center of buoyancy of the envelope, so that balance is not affected when they become empty. The gasoline drains from these tanks to a pair of pressure tanks under the floor of the car. Each pressure tank contains fuel for an hour's run under air pressure from an engine-driven air pump. Gasoline under pressure feeds from the pressure tank direct to the engines. The engineer shifts over from one pressure tank to the other every hour. This system was adopted to keep pressure off the main tanks, which are of light metal, and to eliminate the head resistance of an overhead gravity tank. It works well.

The car is protected from bumps against the ground by two pneumatic cylinders of rubberized fabric, which fit in cradles under the floor. Parachutes for the crew are carried in aluminum buckets let into the bottom of the car so as to be out of the wind. To save resistance, the drag rope which is to be let down to the landing party is coiled up in the bow compartment. The bottom of this compartment opens down like the lower jaw of a fish and permits the coil of rope to fall out. The pilot has only to step on a pedal to throw down his drag rope.

The controls are separated. The direction pilot sits in the front seat and steers the ship by compass, having nothing else to do, while the altitude pilot sits in the rear seat and controls the course in a vertical plane. He has the elevator controls to look after, and, in addition, all valves, ballast and pressure-regulating devices on the envelope. His duty is the more exacting and requires experience. He controls the pressure of the gas in the envelope by letting air into the ballonets. For this purpose scoops can be let down into the slip stream of either engine, and there are valves to permit discharge of air into either the forward or after ballonet or to both. The mechanician in the next compartment handles the engines on signal and looks after the fuel supply.

The operation of the ship is therefore divided among three men, who form the minimum crew. The fourth compartment is for the radio operator. The usual radio apparatus is carried, including radio telephone and direction finder.

The C-5, in its flight from Cape May to Newfoundland via Montauk, for the first time carried its radio antennae inside the envelope. The installation was successful in every way. Even when the airship was moored close to the ground at Cape May, messages were sent for nearly a hundred miles and were received from the naval air station, Coco Solo, Panama. The C-5 on this trip also carried a hydrogen carburetor, a development of the British Admiralty. By means of this device when it would normally be desired to valve hydrogen during the course of the airship's flight in order to control altitude, instead of valving hydrogen into the atmosphere, hydrogen gas from the envelope is burned as fuel in the engines, thereby effecting a saving of gasoline and increasing the radius of action of the airship.

Kite Balloon Progress

In discussing progress in lighter-than-air craft, I should not omit the kite balloon. While the kite balloon is not a self propelled airship, it is a very pretty engineering job and has caused us first and last a lot of trouble. The kite balloon as a design we took bodily from the British and our troubles came in reproducing it with our materials and in attempts to improve some admittedly weak points. The work done in that connection is not, however, different in kind from what I have already gone into.

The telephone cored cable is a typical feature. The great advantage of the kite balloon, and in fact its only reason to exist, is the facility and certainty of communication by telephone to the ground. Other aircraft use radio and are subject to all sorts of interference and uncertainty.

In the early days of the war telephone communication from a ship's deck with kite balloons was held by means of a twisted pair of conductors independent of the holding cable, let down on a reel from the basket. Subsequently, it developed that a cable with a core of telephone wires was greatly desired to replace the outfit of cable and separate conductors, and that such a telephone core cable was being used successfully by the British and French. The British cable consisted of three single conductors each enameled, silk covered, twisted, and then covered with a thin insulation of rubber around which was spirally wrapped a brass strip to serve as protection between the delicate core and the strands of the cable proper. Equipment for producing the thin supplementary rubber insulation required by the British cable was hard to find in this country. Consequently, a cable was developed by the American Steel & Wire Co., with a telephone core of three copper conductors each enameled, silk covered, twisted, and covered with a single layer of cotton, and finally insulated with high grade rubber of thickness equal to the combined thickness of the supplementary rubber insulation and the brass strip of the British cable. This cable has proved satisfactory without the brass armor on the core, and from the results of service is believed to be as rugged as the foreign cable.

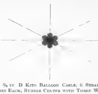

Fig 14. 3/8 in D Kite Balloon Cable, 6 Strands of 19 Wires Each, Rubber Center with Three Wires

In the fall of 1917 steps were taken to develop suitable winches for handling kite balloons—a steam winch for use on small towing vessels, a gasoline-engine-driven winch for use on shore stations, and later an electric winch for use on capital ships of the fleet. The principle of the single drum cargo winch with slipping frictions was tried and was found unsuccessful on account of the compression strain on the cable due to the superimposed layers on the drum crushing the telephone wire core. We next tried a "surge drum" winch equipped with one or more winding of "surge" drums on which the cable is laid in grooves in a single layer, and a storage drum, independent of the winding drum. The winding drums exert all the pull on the cable which is stored on the storage drum under light tension. By this method the cable on the storage drum is not subjected to the severe crushing stress which would result from superimposed layers of cable put on under high tension. The gasoline-engine-driven winch of the N-C-L Engineering Corp. was the first one developed and a notable improvement over former experiments was the use of the Entz magnetic transmission, such as is used on the Owen magnetic automobile, for transmitting power from an 8-cyl. Herschell-Spillman engine to the winch unit. This afforded a very wide and flexible range of speed control.

In the spring of 1918 the first of the electrically operated winches was worked out for use on capital ships. The winding unit of these winches was identical with the gasoline-engine-driven type and the Standard Electric Co. crane motor with appropriate controller replaced the gasoline engine and magnetic transmission.

A successful steam-engine-driven winch was completed about the time of the armistice. The usual slow speed steam winch engine had to be discarded as not giving the necessary flexibility in control of the winch nor the speed desired in quick hauling down, and a small radial-cylinder sleeve valve high speed steam engine was successfully worked out by the N-C-L Engineering Corp. which solves the difficulties of a proper steam power plant. With the completion of this steam unit, the Department has now reached a point where satisfactory kite balloon handling winches are furnished using a standard winding unit with any one of three different power plants (gasoline, electricity or steam) for use on various type of vessels and on shore stations.

Lightning has always been one of the chief enemies of kite balloons, and at the beginning of the spring, 1918, a large size strain insulator was regularly interposed between the

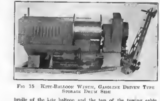

Fig 15 Kite-Balloon Winch, Gasoline Driven Type Storage Drum Side

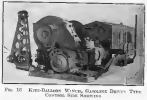

Fig 16 Kite-Balloon Winch, Gasoline Driven Type Control Side Showing

bridle of the kite balloon and the top of the towing cable. This, of course, added a good deal to the weight of the kite balloon, but was believed to be a sure protection against destruction of the balloon by lightning. Balloons so equipped gave excellent service until August 1918 when the U. S. S. Gloucester towing a large 35,000 cu. ft. type R Caquot kite balloon at 500 ft. altitude anchored off the Section Base opposite Naval Air Station, Rockaway, L. I., during a heavy storm. Lightning struck the balloon, completely destroyed it, and coming down through the bridle cables exploded the strain insulator and a theory which had held true many months through good luck.

Construction of Rigid Airships

The employment of Zeppelins by the Germans for naval purposes was so successful that it was obviously necessary to make some sort of provision for their construction if we desired to keep up with the times. The task of building such tremendous structures while in the midst of an intense campaign of war preparations was too much to be undertaken at that time so we contented ourselves with making certain that all of the materials required would be available when the proper time came.

One of the most difficult materials required was the aluminum alloy for the structural frame, which had never been manufactured in this country. Inquiry regarding this was sent to the Aluminum Co. of America in 1916 and they undertook in cooperation with the Bureau of Standards to produce such material. They were given samples of German Zeppelin wreckage obtained abroad. This was analyzed, duplicated as to chemical composition but did not develop the desired strength until a correct heat treatment was finally hit upon. Experimental girders were made up for test to get design data and to develop the manufacturing processes in manipulating the alloy. I am very happy to say that after two years of work, an American alloy has now been produced which appears to be satisfactory in every way and to exceed slightly in strength and elongation the original German samples.

This is an alloy of aluminum containing about 4.5 per cent copper with smaller amounts of manganese, magnesium and silicon. In the soft condition as it comes from the heat treating both the tensile strength is about 40,000 lb., but in 24 hr. it seasons and hardens to 60,000 lb. tensile (15 per cent elongation). It, therefore, duplicates mild steel in strength but weighs less than half as much. In the soft condition it may be bent, stamped and worked cold into useful shapes and will harden afterward without subsequent warping or heat treatment.

We knew that the German gas cells were made of a cotton fabric covered with goldbeater's skin, which was of a high degree of resistance to the passage of gas, but we had no knowledge of the processes by which this delicate membrane was attached to the fabric or kept in proper condition. Experiments were begun at an early date and are continuing up to this time on various methods of attaching goldbeater's skin to the cloth, and we now have two successful methods, each presenting advantages over the other and each resulting in a fabric of high quality. One method uses the skins green as they come from the pickle and the other requires preparation into a sheet which is then fixed to the cloth by a cement much in the same fashion as rubberized fabric is plied together.

Fabric showing diffusion as low as 0.2 liters per square meter has been produced weighing only 5 oz. per sq. yd. (The notation appears mixed but is that of the chemist in the first case and of the textile trade in the second.)

There has been a continuous endeavor both here and abroad to produce some sort of an oil or compound which might be applied to cloth and which would give the same resistance to the passage of hydrogen as goldbeater's skin. So far nothing has been discovered equal to goldbeater's skin, that is, nothing of similar weight. Our experiments however have resulted in the development by Lieut. H. A. Gardner, of the Bureau, of tung oil coatings which approximate the resistance to permeability of goldbeater's skin very closely. When varnished they equal the true skin and are only slightly heavier.

Special engines for airships have not been developed in the United States to any extent and we have been using airplane engines running at reduced power to get reliability. This necessitates changes in oiling and different jets for the carburetor. The airship engine should resemble the automobile engine more than the airplane engine. It normally runs at from one third to one half full power, only in the case of a strong head wind is full power called for. The airplane engine always runs full power at the start and when climbing, and not below three-fourths power the rest of the time. Ten or twelve hours is a good run for heavier-than-air craft, but in an airship we have already cruised for 40 hr. with one of our little ships and the British record is over 100 hr. The Union Gas Engine Co. of Oakland, Calif., has attacked the problem of producing an airship engine and their 6-cyl. engine will be the standard equipment for all airships of the C and D classes. It has shown great reliability and very low fuel consumption over a wide range of powers.

The Liberty engine is apparently one of the most versatile of creatures. Lacking a large engine similar to the Maybach, we turned to it as a possible airship engine and found that at from 250 to 300 hp., the power of the Maybach, the Liberty was at least as economical, no heavier, and apparently as thoroughly reliable and capable of operating for indefinite periods.

One of the greatest problems in connection with the rigid

airship is that of maintaining the ship at a constant elevation as the fuel is burned out. Ordinarily this means that as the ship grows light, gas must be valved and the possibility of rising to greater heights in the future is consequently reduced. There have been many projects put forward for the prevention of this, including the taking up of water from the sea and the condensation of the moisture in the exhaust gases. Theoretically it should be possible to recover from the exhaust gases of the engine 1½ times the weight of the gasoline burned, but so far no one has ever succeeded in doing this with an apparatus which is practicable for use on an airship. The Bureau of Steam Engineering has, however, been conducting experiments and has developed an apparatus which has succeeded in condensing as high as 99 per cent of the weight of fuel burned and has kept the weight within practicable limits. When it is considered that the best previous record for a similar apparatus which could be carried in the air was about 55 per cent, it is believed that a notable improvement in airship operation is due.

In discussing lighter-than-air progress, I should like to point out that while the airship is now being pushed by the Navy, we have had a late start. Compared with the NC flying boat, which is in advance of anything in the world, our best airships, the C class, while as good as or better than any of equal size, are very small indeed compared to a Zeppelin. Consequently we may expect progress in airship design in the United States to be more rapid in the next few years than in aeroplanes.

The Licensing of Aeronautical Engineers and the Inspection of Aircraft

By G. Edward Barnhart

The following article contains many interesting suggestions, but, while there is no doubt that pilots should be licensed for civilian flying, there would seem to be a difficulty in the question of licensing aeronautical engineers, and there is no precedent in any other branch of engineering for such licensing. It is also doubtful whether there is at present a shortage of aeronautical engineers. The suggestions regarding reports on wrecks and the maintenance of logbooks are very valuable. Discussion of this article is invited.—Editor

Aeronautical engineers should be licensed and all aircraft should be inspected before they are flown. It has been found necessary that boat captains should pass an examination and be licensed, and that all public utilities, such as boats, railroad equipment and elevators, should be inspected by competent government inspectors, to insure the safety of the public. In order to protect life and property, the Government and other bodies found it necessary to license pilots for military and civilian flying. With the same logic in mind, why should we not license aeronautical engineers? It is certainly of as much importance to have qualified men design and build a machine as it is to have a competent pilot.

Need of Organization to License Engineers

This being the case, it is very evident at this time that we are in need of a new organization to examine and license aeronautical engineers for their respective duties. The commission or committee for this work should be organized and handled by the Government in a manner similar to that of licensing pilots of aircraft of either the lighter or heavier than air types. This branch of work is very important and most vital, for we have from time to time many engineers holding positions for which they are entirely unqualified. By virtue of their positions they are left to make decisions which only a highly trained man should make. At this period of readjustment, when the aircraft industry is on the threshold of its future development and realization, this phase of the subject should not be left without proper attention.

In the early development of the heavier-than-air craft it was seen that the pilot or mechanician bore nearly as much weight in his suggestions and criticisms of aircraft design and its serviceability as the more highly trained aeronautical engineer and educated man. It was also the case that many times the suggestions of the pilot were contrary to the opinion of the engineer. While a great many pilots know their machine thoroughly from the standpoint of operation, inspection and actual construction, it is neither their duty nor calling to necessarily understand aerodynamics as would an engineer. This is said with all due credit to our pilots. Again, cases have occurred where pilots would be influenced by laymen that certain parts would serve as well in the construction of their machine as those which were recommended for use by the engineer. Consequently, the pilot went out with a machine which was structurally weak, although in his own mind he believed it to be safe. The outcome of this was often an accident or a fatality.

Owing to lack of time during the rush of war many men were called to fill positions as aeronautical engineers in the aircraft industry for which they were entirely unqualified. This is by no means a reflection on either the employer or employe, but a condition brought about by the exigencies of war.

Too much credit cannot be given to the Government for their training and development of pilots, mechanics and engineers. However, if the airplane is to become a potent commercial factor, now is the time when we must put it on a firm basis.

Improving the Engineering Standard

In this article it may appear that licensing engineers is meant to protect only the pilot and the general public, but it is hoped that it will help improving the aviation industry by weeding out all the unqualified and by supporting the manufacturers in their work of development. It is hoped that the engineering standards of aeronautics will be improved by this plan, which is in direct alignment with the movement of states and organizations to license all practicing mechanical, structural or civil engineers, as thus only the qualified may make a practice of engineering.

Now there is a shortage of qualified aeronautical engineers to fill positions in the various departments. To established companies the worth of a capable engineer is inestimable. In many cases, however, we find the engineering department reduced to a minimum. This should not be the case, for even though the engineering department is a direct overhead charge, the value of that department through efficient methods and men will do much for the success of the company and aviation in general. As we see it in other engineering pursuits, the time is arriving when the engineer and the engineering department are receiving more consideration than they ever have in the past.

Examination and Qualification

Should the plan for licensing aeronautical engineers be adopted, they should be examined by a written or practical examination, as well as by documentary proof of their standing, training and experience. They should either be able to fly or be sufficiently well versed in the subject to thoroughly understand all conditions of a machine in flight. The engineer should be capable of calculating and checking the design of a machine and properly aligning and adjusting it for flight or correcting any of the faults which may occur in design, alignment or flight.

In engine design and inspection the engineer should be able to run such tests on new or used engines as will determine their fitness for use in aircraft. In the case of older designed and used engines, the engineers should understand them so as to be able to decide whether or not these engines are serviceable for any flying.

Inspection Reports and Advantages

Having adopted the plan of licensing engineers, the pilot should turn in to the Government or some authority reports signed by a licensed engineer who has thoroughly inspected

both the airplane and the engine. Similar reports should be made at stated periods, depending on the use of the machine, but approximately at the end of each hundred hours of flying. At such times as a repair has been made or the machine been badly strained, it should be inspected before taking the air. The pilot or owner of the machine should carry his license, as well as this certificate, showing that the machine is in a satisfactory condition.

Although the inspecting engineers need not be in the employ of the Government until such a time that the air service would demand it, it would be well to hold these registered engineers at the service of the pilots, who will require the certificates of clearance. When the expansion of the aeronautical industry is such as to warrant it, both the pilot and the engineer should take civil service examinations and be held under the same ruling and jurisdiction.

The privately owned single and double-seater airplane should necessarily come under an occasional inspection by qualified persons. The inspection will be found to be of considerable advantage as in the case of the sportsman who uses the machine only occasionally and who will want to be assured that the machine is in the best of condition when it is in use. A consultant will often relieve the owner, pilot or mechanic of worries of unusual occurrence and clear up in their minds any outstanding problems that come up between inspections. This would serve to create interest in a mechanical and scientific side of aviation.

Undoubtedly the chief engineer or several engineers of each corporation will be licensed, and they will bring the system to a still higher efficiency. In the case of a small company or individuals building single machines, it should be necessary for them to have a licensed engineer inspect their design and the machine before it is flown. Should the engineer decide that the machine is unsafe or of freak design, it should not be passed as satisfactory to service. The builder of the craft may consider it unfair to him, and he should have recourse to two or three aeronautical engineers in consultation. Their decision should be final.

Moreover, a licensed aeronautical engineer for the inspection of aircraft would reduce the work of training pilots, inasmuch as it would only be necessary to give them a general understanding of the airplane, instead of a more detailed one as is now necessary with them acting as their own inspectors. Should the pilot so desire, there is no reason why he himself should not be licensed as an inspecting engineer providing that he can pass the examination.

After each accident an engineer should be called in to photograph and report on the wreck. A report should be made of minor, as well as major, defects of the airplane or engine. All information which it is possible to procure should be embodied in the report including the testimony of qualified persons in describing the accident. After making this report, the engineer should make recommendations for repairing the ship, and he should again inspect it on the completion of the repair work. In case of salvaging a machine, the engineer should inspect all salvaged parts. A similar course was adopted by the United States Government at its flying fields, and it should be followed in future aircraft inspection.

The fee for these inspections could be a standard one depending on the machine, its age, and the ease with which the inspector might reach the place where the machine is located; or the fee might be included in the yearly license tax of the owner or the pilot.

No attempt is made here to dictate the policy on which a flying field shall be run, although at a later date inspection might be required for them. This inspection would cover their equipment and their location as regards accessibility from the air, also such items as wind, fog, drainage of the field, or any other climatic or topographical conditions.

Maintenance of a Logbook

The maintenance of a logbook for both the airplane and engine should be required. This should show all breakages and repairs, as well as any irregularities in the handling of the machine in the air or on the ground. Various individuals and corporations have maintained similar logbooks, but a higher degree of efficiency would be reached by adding the notes concerning the handling of the machine in the air. All commercial aircraft should be required to maintain these. The British Parliamentary Investigation Committee on Civil Aerial Transport has gone to some length in requesting the examination of all wrecks and accidents by qualified persons, and here the logbook plays an important part. The inspectors of a damaged or wrecked machine often require its previous history. This need will be filled by a logbook giving general remarks as to repairs of the machine, changes in design made necessary from breakages or suitability to the work which they are doing, or the failure of any fittings or wood parts.

It is not the writer's intention to act as an adverse critic toward our present system, or in any way to try and dictate a future policy. Neither is it his desire to cripple the industry by added expense, but rather to remove unsafe and freak machines from commercial travel. It has been called to his attention in many ways, both large and small, that there is a great need for an improvement in the engineering standard of air travel. It is thought that this standard may be attained when only the mechanically safe machines are allowed to fly.

A New Liberty Engine

The War Department has developed a 24-cylinder Liberty motor which has just been successfully tested at McCook Field. Originally the Liberty motor was designed for eight cylinders, then enlarged to twelve cylinders. The engine used in the test at McCook Field was built of standard Liberty twelve parts. The changes were few, consisting chiefly of the use of two regular crank case upper halves, one of which was somewhat altered, and special design connecting-rods.

The following table compares the Liberty 12 and the experimental Liberty 24.

HORSE POWER (NORMAL)			
Liberty 24	873	Liberty 12	400
POUNDS PER H. P. (DRY)			
Liberty 24	1.97	Liberty 12	2.11
GAS CONSUMPTION (POUND) PER H. P. AN HOUR			
Liberty 24	.55	Liberty 12	.51

The experimental Liberty 24 compares favorably with successful tests of foreign motors of approximately the same power. An engine of this power, if run at the normal speed, would enable the use of a comparatively large slow-speed propeller without gear reduction, thus increasing propeller efficiency.

The following table compares the Liberty 24 and various high-powered foreign motors.

Motor and Country of Manufacture	H. P.
De Dion, France	800
Liberty 24, United States	*873–738
Fiat A 14, Italy	600
Rolls Royce "Condor," England	600
Anzani 20, France	500
Renault 12-M, France	550
Salmson 18-Z, France	500
Napier "Lion," England	450

* Experimental, not rated

London-Paris Air Transport Service

A new freight and passenger airplane service between London and Paris was inaugurated Aug. 25. The results of the first day's operation show that this means of communication is entirely satisfactory and far more comfortable and speedy than the old systems.

The airplane 4-A left London at 9.08 o'clock and returned at 2.45, completing the round trip in five and three-quarter hours. Two firms have started daily flights simultaneously, charging $75 to $100 single fare. Considering the advantages, these prices are not held to be exorbitant. Great hopes are held out that these fares will be reduced as operating conditions become better, and with bigger, better planes capable of carrying heavier loads.

These planes carry one ounce of mail for $1. As it is possible to send 5,000 words for this sum, the rate is considered cheap. Cable tolls to Paris average 5 cents a word, and the airplane men say they will soon be able to beat the cable. The manufacturers say they have plans for reducing the time between the two cities to one hour, and that this may be realized in one year.

Drops Mail on Ship

The first air delivery of late mail for outgoing ocean liners was ingeniously accomplished August 14, when an Aeromarine flying boat dropped a pouch on the White Star liner *Adriatic*. The first was successful despite adverse weather conditions and a heavy sea, an hour and a half after the *Adriatic* left port.


HISPANO-SUIZA
Aeronautical Engines
"The Motor that made the Spad possible"
Into each operation in the manufacture of
HISPANO-SUIZA AERONAUTICAL ENGINES
goes the engineering experience and ability of this great Organization, drawn from the leading minds of the profession.
—Which perhaps best explains the engine's many superior differences.
Wright-Martin Aircraft Corporation
New Brunswick, N. J.
Boring Water Jacket Castings

Course in Aerodynamics and Airplane Design

Part III.—Experimental Aeronautical Engineering

By Alexander Klemin

Technical Editor, Aviation and Aeronautical Engineering, Consulting Engineer, Aerial Mail Service, Consulting Aeronautical Engineer

Section 8.—Wind Tunnel Experimentation

Recent Progress in Aeronautical Laboratories

In Part I, Section 1 of this course (AVIATION AND AERONAUTICAL ENGINEERING, August 1, 1916) under the title "Modern Aeronautical Laboratories," a fairly complete review was given of the aeronautical laboratories then in existence. Progress since that date has been rather in size than in development, the general characteristics of both tunnel, balance and subsidiary instruments remaining substantially the same. Propeller wind tunnels which have developed will not be included in this course, nor the methods developed in the investigation of stability.

National Physical Laboratory (England)

The first effective N. P. L. tunnel was of 3 ft. x 3 ft. section. The following table indicates the classes of tunnel now in use:

COMPARISON OF WIND TUNNELS AT NATIONAL PHYSICAL LABORATORY

	No. 1 7 ft.	No. 6 7 ft.	No. 1 4 ft.	No. 2 4 ft.
Overall length			52 ft.	52 ft.
Length of parallel portion	41 ft.	41 ft.	26 ft.	26 ft.
Intake to balance	30 ft.	25 ft.	6 ft.	6 ft.
Length of distributor	25 ft.	30 ft.	21½ ft.	21½ ft.
Length of cone to propeller	10 ft.	18½ ft.	4 ft.	4 ft.
Angle of cone (internal)	20 deg.	20 deg.	30 deg.	30 deg.
Diameter of propeller	10 ft.	11¼ ft.	6½ ft.	6½ ft.
Effective pitch diameter*	0.50	0.7	0.50	0.72
R.p.m. at 60 ft. per sec.	1000	810	1300 (50 ft. sec.)	1300
Power absorbed at 62 ft. per sec.	46 hp.	32 hp.	8 hp. (50 ft. sec.)	14.6 hp.
R.p.m. at 60 ft. per sec.		1216		1920
Power absorbed at 60 ft. per sec.		133 hp.		58.3 hp. (70 ft. sec.)

* Effective pitch is calculated from air speed in the tunnel just before the propeller (neglecting increase of velocity due to inflow) divided by revolutions per minute.

In discussing the N. P. L. tunnels, J. R. Pannell states that the 7-ft. No. 2 tunnel is not an exact copy of the No. 1. The buildings in which they are housed are of approximately the same size, but, as the newer tunnel is supported on steel frames instead of concrete columns, the obstruction to the flow of air returning to the intake of the tunnel is appreciably less. In spite of the increased area available for the returning air, the No. 2 7-ft. tunnel is less steady than No. 1. This is possibly due to the reduced length of the distributor and increase in effective pitch of the propeller, which means that the propeller is working at a larger angle of incidence for the blade elements and therefore in a condition of more disturbed flow.

Curtiss Tunnel of the Eiffel Type

The new 7-ft. Curtiss tunnel is of the Eiffel type, but presents some novel and interesting features. It is suspended on steel cables from the ceiling of a room 103 x 30 x 35 ft. This allows a somewhat less disturbed movement of the air than where the tunnel is mounted on steel columns.

A 400-hp. Liberty motor with a three-bladed propeller is used for the air circulation. The collector portion of the tunnel is 15 ft. long. The entrance diameter is 17 ft., and the diameter at the wall is 7 ft. The diffuser starts at the experimental chamber and with a diameter of 8 ft. and gradually enlarges until at the motor end it is 12 ft. in diameter. The diffuser has a length of 37 ft. The experimental chamber is of the Eiffel type, and has a length of 15 ft. and a width of 13 ft. It is thus of much greater diameter than the rear end of the collector or the front end of the diffuser. The main advantage of this large experimental chamber is that it permits the observer to stand within the chamber to adjust a model, or even to observe while the experiment is in progress. It is also claimed that this type of experimental chamber prevents pocket-action due to the sides of the tunnel as in the N. P. L. type.

Definition of Tunnel Efficiency, Efficiency of Various Tunnels

Tunnel efficiency may be divided into two parts:

$$\text{Channel efficiency } e_c = \frac{\text{Kinetic energy of stream in experimental chamber}}{\text{Useful power exerted by propeller}}$$

$$\text{Overall efficiency } e_o = \frac{\text{Kinetic energy of stream in experimental chamber}}{\text{Power required to drive the propeller}}$$

The useful power exerted by the propeller may be defined as the thrust of the propeller into the velocity of the air-stream in front of the propeller, extra velocity of inflow not being considered. This may be computed for any given propeller, but as we have insufficient data for this purpose, it seems more useful to consider the overall efficiency of the various tunnels for which figures are at hand, assuming standard air at 15 deg. C and 760 mm. or .07608 lb./cu. ft.

(a) N. P. L. No. 1 4-ft.; 8 hp. at 50 ft./sec. Overall efficiency = .54

(b) N. P. L. No. 2 4-ft.; 14.6 hp. at 62 ft./sec. Overall efficiency = .56

(c) N. P. L. No. 1 7-ft.; 48 hp. at 62 ft./sec. Overall efficiency = .56

(d) N. P. L. No. 2 7-ft.; 56 hp. at 62 ft./sec. Overall efficiency = .48

As an example of a small tunnel, there is the East London College tunnel, 2 ft. square, with an overall length of 23 ft. 8 in., of exactly similar type to the N. P. L. tunnel. It is provided with a 3 ft. 6 in. diameter four-bladed steel propeller with varying angles of blade.

(e) East London 2-ft. tunnel overall efficiency.

5 hp. at 38 m.p.h. or 55.5 ft./sec. = .298
1 hp. at 20.5 m.p.h. or 30 ft./sec. = .232

Two Eiffel tunnels were described in Part I, Section 1. These are of the Venturi type with a chamber at the throat of the Venturi. The larger channel has a bell collector with end diameters 13.1 and 6.6 ft., with a length of 10 ft., and an expanding trunk 29.5 ft. long with end diameters equal to the collector. The expanding trunk connects with a suction blower, having a sectional area of 97 sq. ft. In the experimental chamber the air stream is 6.6 ft. in diameter.

In this channel a maximum velocity of 105 ft./sec. is obtained with a 50 hp. electric motor, driving a 50 per cent efficient Sirocco blower.

(f) Eiffel 6.6 ft. diameter. 50 hp. at 105 ft./sec. efficiency = 1.73

This efficiency—and strictly speaking this is not efficiency, but a utilization coefficient—is surprisingly high, particularly in view of the low efficiency of the Sirocco fan. No doubt the Eiffel tunnel is more efficient than the N. P. L. type because of its comparatively short length, consequent reduction in friction losses, and because of the absence of sharp breaks in section.

In the small Eiffel tunnel there is a bell collector with ends 6.6 ft. and 3.3 ft. in diameter, 5.27 ft. in length and an expanding trunk 19.2 ft. long connected to a Sirocco suction blower. The diameter is 3.3 ft.

(g) Small Eiffel tunnel 3.3 ft. diameter, 131 ft./sec. with 50 hp. Efficiency = .825, which, although much lower than in the large Eiffel is higher than any of the N. P. L. values.

(h) In the Curtiss 7-ft. wind tunnel, Dr. J. G. Coffin states the maximum speed to be 95 or 96 m.p.h. with the low compression Liberty engine turning about 1175 r.p.m. which corresponds to about 225 hp. This gives an efficiency of 1.35, which compares well with the Eiffel tunnels, particularly as

this is the maximum speed, at which the efficiency of a tunnel generally falls off.

(i) No data is available for publication on the closed circuit tunnel at the Washington Navy Yard, but in a recent issue of AVIATION AND AERONAUTICAL ENGINEERING complete data is given for the tunnel of the Instituto Centrale Aeronautico of Rome. With a seventeen-blade wooden propeller of efficiency .75, and a 2-meter experimental chamber the horsepower required at 40 meters per second was 60 m.p.h., giving an efficiency of 3.64. This surprisingly high figure is no doubt due to the fact that in a closed circuit tunnel, discontinuity of flow is entirely avoided.

The closed circuit tunnel also offers the advantage that a comparatively small building can be employed to house it. It is possibly the heating of the air and the persistence of eddies in a closed circuit that prevent the wider adoption of this type.

Design of the Propeller for a Wind Tunnel

To an experienced propeller designer, there is no difficulty

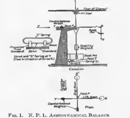

FIG. 1. N. P. L. AERODYNAMICAL BALANCE

in designing a suitable propeller on the ordinary airplane propeller basis. Given the velocity of air in front of the propeller, a suitable expression for the inflow and outflow, the propeller can be designed on the basis of the thrust required by a slight variation of usual propeller design methods.

Principle of the Aerodynamical Balance

While the Eiffel tunnel has a greater coefficient of utilization than the N. P. L. tunnel and with large experimental chamber offers many other advantages, it can be safely said that the N. P. L. balance is far superior, permitting readings to be taken more quickly and with less subsequent computation.

A sketch due to W. L. Cowley and H. Levy in Fig. 1 illustrates this balance diagrammatically, and an explanation of this sketch will serve as an introduction to the fuller description given later.

The model to be tested M is fixed in position as shown with the wind blowing in the direction FM. The instrument consists of an upright support PAM passing through the channel floor. At A is an oil seal whose function is to prevent disturbances by air being drawn through into the channel from the outside. $APQRT$ is all one piece supported at the single point P of the fixed standard B. R is a stability weight, which, when its position is varied vertically, causes the sensitiveness of the balance to be adjusted.

In operating the balance the arms PQ and PQ^1 are balanced by weights until they are in a horizontal position. When they are in a horizontal position, the dimensions of the parts being known, the forces on the model, both lift and drift, can be readily determined.

The forces on the two arms can be obtained simultaneously, while the balance must be freely pivoted at the point P during these measurements, it must be prevented from rotating about the vertical axis by constraining the arms by means of a strut and spring C connecting the portion PY to the fixed standard.

For the measurement of the moment on the model about the vertical axis, the strut and spring C are removed and replaced by a calibrated spring and the screw at S loosened until the spring Sp bears upon the point T. The balance is now capable of rotation only about the vertical axis TP, and by measurement of the degree of compression or extension of the cali-

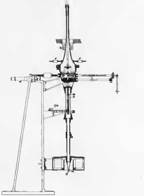

FIG. 2. TYPICAL WIND TUNNEL BALANCE

brated spring required to bring the balance to its normal position the moment can be determined.

Drawing of a Typical Aerodynamical Balance

In Fig. 2 is shown a drawing of a 4-ft. wind tunnel balance, which is typical in every way, and in Fig. 3 is shown a photograph of a balance of exactly similar type though employed in a different laboratory.

With the preceding introductory paragraphs and a brief description, the reader should be able to follow the above drawing.

For the purpose of measuring lift and drift the balance in Fig. 2 is supported on a single point O. S is the oil seal previously mentioned. By means of the movable weights F the center of gravity of the upper part of the balance is made to lie on the axis of rotation. A vernier and clamping arrangement enable the model to be placed at any angle required to the wind. By means of the screw adjustment K, the balance is either thrown into the lower pivot when it is required to find turning moments or released, when lift and drift forces are required. The wire T when in position is a torsion wire used to measure the moments on a model. The balance can be made to rest either on the point O or on the two points P. For a

detailed description of the balance the reader is referred to original reports.

Wind Tunnel Velocity Instruments

Apart from the balance, wind tunnel experimentation requires a large number of subsidiary instruments, such as oscillators, special devices for testing one surface in the presence of another, and many other pieces of apparatus which the operator has to devise and build for himself. The velocity measuring instruments are more or less standardized and some of them are purchaseable. These include:

Pitot Tube

A full description of this was given in Part 1, Section 2. The Pitot tube is indispensable in the initial calibration of the tunnel, and in exploring the cross-section of the tunnel for regularity of flow, but it is not suitable for measuring the velocity of flow of the tunnel during experimentation, as even

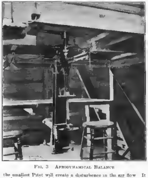

FIG. 3 AERODYNAMICAL BALANCE

the smallest Pitot will create a disturbance in the air flow. It is therefore replaced by a side plate as shown in Fig. 4.

Side Pressure Plate

The theory of the side pressure plate is very simple. If p = pressure at any point in a streamline, v = velocity at any point in a streamline, d = density at any point in a streamline, and p_o = pressure where v is zero, then by Bernoulli's theorem

$$p + \frac{dv^2}{2g} = p_o$$ if friction losses are neglected.

In an open-circuit wind-tunnel of the N. P. L. or Eiffel type the fan sucks air through the tunnel which is therefore all under suction. The air is discharged by the fan through a strainer into the building at one end, whence it returns at low velocity to the other end to pass again into the tunnel.

At a point in the room the total pressure, which would be transmitted by a pressure impact tube would be $p_r + \frac{dv_r^2}{2g}$

$= p_o$

The quantity $\frac{v_r^2}{2g}$ is so small however, owing to the low return velocity in a large room, that it is possible to write

$$p_r = p_o = p + \frac{dv^2}{2g}.$$

If therefore a hole in the side of the tunnel is connected with one end of a liquid manometer, and the other end of the manometer is left open to the room, the gage reading will be $p_r - p = p_o - p = \frac{dv^2}{2g}$, so that the reading of the manometer is a measure of the velocity.

Strictly speaking $p_r = p + \frac{cv^2}{2g} + p_f$, where p_f is a measure of the friction losses. The error due to the side plate is of the order of 3 per cent. It is therefore necessary to calibrate the

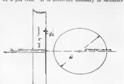

FIG. 4 SIDE PRESSURE PLATE

side plate and its manometer against the standard Pitot tube and its manometer.

The side plate shown in Fig. 4 consists of a thin brass disk about 3 in. in diameter, set flush in the wall of the tunnel. The disk is flat and highly polished. Near its center, five holes 0.02 inch in diameter are drilled. These holes are connected with a brass tube soldered to the back of the plate and projecting through the side of the channel. Rubber tubing is used to transmit the static pressure from the small holes to one end of a manometer.

The pressure transmitted by the side plate has been found to respond very quickly to changes in velocity, and the method

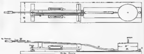

FIG. 5. ALCOHOL MANOMETER

is even more sensitive than the Pitot tube. Naturally its precision is no better than that of the Pitot used for its calibration.

The pressure difference transmitted by the side plate is read on an inclined alcohol manometer on the Krell principle. Both the side plate and this alcohol manometer require calibration against a standard. For convenience, the side plate and its manometer are calibrated together against a standard Pitot tube and a Chattock manometer. The procedure in such a calibration is obvious.

The Krell Manometer

The ordinary U-tube manometer filled with water, gasoline, alcohol, or other light liquid, shows a head of less than 1 in. for ordinary velocities, and it is impracticable to read the movement of the meniscus. An inclined manometer such as the Krell gives a much larger displacement for a given head. This manometer is shown in Fig. 5. One leg of the U-tube is an inclined glass tube and the other is a reservoir bottle whose section is some 400 times the section of the tube. Hence, as

liquid rises in the glass tube, the depression in the reservoir is unimportant.

As shown in Fig. 5, the reservoir R is mounted in a hinged plate with leveling screw. By means of the latter the liquid in the tube is brought to the zero of the scale at the beginning of a test, thus making a zero correction unnecessary. The glass tube T is likewise mounted on a brass plate pivoted at the knife edge K, and adjusted in pitch by the screw S. To the brass plate are attached permanently two small machinists' levels L_1 and L_2 set at 3 deg and 8 deg to the axis of the tube. For a low velocity the 3 deg inclination is used. Displacement of the liquid in the tube T is read on a scale graduated to half a millimeter. The head is given by the formula

Head of liquid = displacement in $T \times$ sine of inclination.

From experimental work at the Massachusetts Institute of Technology, the following conclusions were reached:

(1) The inclined type of liquid gage as commonly employed in ventilation work is not an instrument of precision.

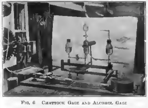

FIG. 6 CHATTOCK GAGE AND ALCOHOL GAGE

(2) For consistent results, the glass tubing used must be free from all slight flaws on the inner surface which might cause changes in capillarity throughout the bore.

(3) The tube must be uniform in diameter.

(4) The tube must be as large as it is possible to use and still get a good meniscus.

(5) For alcohol at 3 deg inclination an internal diameter of 0.22 in. is suitable.

(6) The maximum precision with such a gage used to measure air speeds from 4 to 40 mi. per hr. is about 1.5 per cent on velocity.

(7) The alcohol gage properly constructed is consistent and very sensitive.

(8) The alcohol gage may be used as an instrument of precision when calibrated against a standard.

The Chattock Gage

The Chattock gage is shown in Figs. 6 and 7. The principle of the gage is that of the inclined liquid U-tube, but, instead of giving the tube an initial pitch and observing the change of level of the liquid, the Chattock gage is fitted with an elevating screw and micrometer by which the gage is tilted to balance the pressure difference in its two ends. By reading on the micrometer the amount of tilt given, the head in inches of liquid is computed. By this means there is no motion of the liquid in the glass, and errors due to capillarity and viscosity are eliminated. Furthermore, the condition of the surface of the glass has no effect.

The gage consists of a glass U-tube mounted on a tilting frame T. The pressures to be measured are connected to the bulbs A and C, which are in communication with each other through a horizontal tube bearing a third bulb B at any intermediate point. The bulbs A and C and the lower part of B are filled with water. The upper part of B is filled with castor oil. The water in B and C is in free communication, and hence the oil in B is at the pressure of C. The water in A is led through a thin-walled tube through the bottom of B extending into the castor oil. An excess of pressure in A over the pressure in C will cause water to flow from A into B. A water bubble will then grow at D and expand into the oil. The gage can be tilted so that this bubble remains of uniform diameter. The pressures in A and C are then balanced. To provide this tilting the manometer is mounted on a tilting frame T, which pivots on the knife edges at G and is elevated by the screw F. The whole is carried on a bed frame Z fitted with three leveling screws I, a retaining spring H, and a scale S, on which may be read the full turns of the screw F.

A microscope M, fitted with cross hairs, is mounted on the frame T and directed at the bubble B. A small mirror on the opposite side illuminates the surface of the bubble. The screw F is fitted with a large drum divided into 100 parts. The screw has 20 threads to the inch. The gage is sensitive to one-half of a division on the drum, and hence to a movement of the screw of 1/4000 in.

Before a measurement is taken the bulbs A and C are

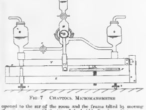

FIG. 7 CHATTOCK MICROMANOMETER

opened to the air of the room and the frame tilted by moving the micrometer until the top of the bubble B is brought tangent to the horizontal cross-wire of the microscope. This is the zero reading. The bulbs A and C are then connected to the two parts of a Pitot tube and the frame tilted until the bubble is again on the cross-wire. The amount of tilt is then read on the micrometer.

For the calculation of tilt it is then necessary to measure the distance between the centers of the bulbs A and C and the distance from the knife edge G to the screw F. An error of 0.1 in. in either of these measurements is an error of 1 per cent in head or 0.5 per cent in velocity. There is no difficulty in getting these distances to the nearest hundredth of an inch. The screw thread is cut so precisely that it is impossible to detect any error in the pitch of the thread. The hole in Z is tapped with a standard Brown and Sharpe tap. The calculation of the change in level of the surfaces of the liquid in A and C is precise to 0.1 per cent.

Since the gage is sensitive to less than 0.1 per cent for heads of more than 0.3 in., the measurement of velocity depends on the precision of the Pitot tube. The latter is good to probably 0.25 per cent in velocity. However, the air current always has some fluctuation at high speeds so that in the end the velocity measurement is limited in precision by the closeness with which such fluctuations can be averaged. In a very steady current, such as our wind tunnel, it is found that the error in estimating velocity is less than 0.5 per cent. The average of a number of observations is, of course, better than this.

Change in density of the salt solution is ⅓ per cent for a change of 60 deg F. in temperature. A temperature correction is ordinarily unnecessary.

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The Trompenburg Pursuit Airplane

The Trompenburg pursuit airplane was built for the Netherlands Air Service by the Trompenburg Automobile and Airplane Manufacturing Co., of Amsterdam, to the designs of Henry Wynmalen, the well-known pre-war aviator. This machine is noteworthy not only as a Dutch sample of modern airplane construction but also on account of its performance, which is remarkably good if one considers the comparatively low powered engine employed. It is obvious from the accompanying illustration that this performance is principally due

The center section is fixed to the fuselage by means of four vertical streamlined struts, while the planes are braced beside the customary wiring by one pair of vertical interplane struts. Two oval cellon windows are let in the center section to increase the pilot's visual range upwards. No stagger, sweepback or dihedral is embodied in the wings, positive ailerons are fitted to both upper and lower planes.

The fuselage is roughly of rectangular cross-section, with slightly domed sides, and is apparently built up on four

Quarter Front View of the Trompenburg Pursuit Airplane

to the clean design of the whole airplane, incorporating careful streamlining of the fuselage, judicious wing bracing and the use of swaged wire for exposed stays.

Both upper and lower planes have a span of 8.10 m., and a chord of 1.42 m. Each plane of either right or left hand wing is of equal span, the upper planes being joined by a center section of 0.85 m. width, while the lower planes are attached to the lower fuselage longerons. This arrangement is distinctly advantageous from the production viewpoint because all planes are structurally identical, although, of course, they are not interchangeable once they are surfaced, this owing to the position of the interplane strut sockets, etc.

longerons with either veneer bulkheads or wire braced cross struts insuring rigidity. Information on this detail is not furnished by the manufacturer.

The power plant consists of an air-cooled 9-cyl. rotary engine, built by the manufacturer, which has a bore of 120 mm. and a stroke of 160 mm. and develops 130 hp. at from 1100 to 1200 r.p.m. Two machine guns are synchronized with the engine for firing through the propeller. The fuel capacity is 28 gal., the oil capacity 4 gal.

The machine has a high speed of 185 km.p.h. (115 m.p.h.) and climbs 1000 m. (3300 ft.) in 2 min. and 3000 m. (10000 ft.) in 11 min.

British Airship Combine

According to the London *Daily Graphic*, a large British airship financial combine, with several millions sterling in money at the back of it, is under course of development. This combine, it is stated in authoritative circles, will be heavily subsidized by the governments of the various European Powers, and will be in active operation before the end of the year.

Three distinct types of airships are to be controlled at the works of the amalgamated companies, situated somewhere in the north of England. Airships of moderate size and high speed will carry express and mails and passengers. Passenger liners of large size and high speed are to be made for longer distance flights, and large airships of comparatively slow speed and large carrying capacity are to be constructed for general transport.

Wealthy travelers are to be catered to with small, non-rigid airships maintained at much the same cost as a small yacht.

It would appear that the Vickers will be one of the members of the above combination.

The Vickers passenger airships under contemplation will be of 3,500,000 cu. ft. capacity, will be housed comfortably in existing sheds, and carry fifteen tons of passengers and mails for a distance of 4,500 miles at a speed of 60 m.p.h.

The main airship routes and times of travel in this scheme will be as follows, all voyages starting from London. To New York, 2½ days; San Francisco, 4½; Cairo, 1½; Colombo, Ceylon, 4½; Perth, Australia, 7; Nairobi, East Africa, 3½; Cape Town, 5½; Rio de Janeiro, 4.

The British western system, to take advantage of the prevailing winds, will consist of two main lines direct and via Lisbon and the Azores to New York and thence to San Francisco. The London to Rio de Janeiro route will be by way of Lisbon and Sierra Leone.

The Messrs. Vickers have already announced a provisional fare of $240 per passenger to New York, and mail rates at 3½ pence an ounce.

Pacific Coast Taxis

The Pacific Aviation Co. of San Francisco, Cal., has established an aerial taxi service on the Pacific Coast. Two passenger planes, piloted by B. M. Spencer, former test pilot at McCook Field and Sam Purcell, former instructor at San Diego, are operated at present between any California Cities, while it is planned to install a fleet of ten passenger carrying planes within the next few months. The two planes now in use are of the Glenn Martin TT type with Curtiss OX-5, 90hp. motors.

The Van Sicklen Chronometric Tachometer

By Frank J. Feely

There are many types of speed measuring devices, which operate upon nearly as many different principles. Some of these have been quite successfully used as automobile speedometers, but on account of the extreme conditions encountered in airplane practice, most of these instruments were not satisfactory, for this use. Extreme temperature variation, change in air density, vibration, and the existence of stray magnetic fields eliminated all but two types of tachometers for satisfactory use on airplanes, namely, the chronometric and the centrifugal types.

Both of these are strictly mechanical in operation, the first measuring speed by time, and the second using the well known principle of centrifugal force which is used in a steam engine governor. The chronometric tachometer is intermittent in action and registers speed every second or every other second,

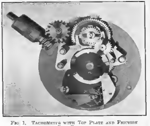

Fig. 1. Tachometer with Top Plate and Friction Disc Removed

while the centrifugal is continuous with the time lag caused by the inertia of its moving parts. The chronometric tachometer has a uniform dial, and since its calibration is controlled by the timing of its watch unit, its accuracy approaches that of a watch. This accuracy is of a very high order, being greater than that of any other speed measuring device. The centrifugal tachometer has a frictional lag which causes it to register less on increasing speeds than on decreasing speeds. This difference in the average centrifugal instrument on the average is nearly 60 r.p.m. in increasing and decreasing speed. The chronometric tachometer does not have this frictional lag.

The general principle of all chronometric tachometers is the same. Speed is measured by time just as with the ordinary speed counter and stop watch. However, the count is performed automatically and in a shorter space of time than it is with an ordinary speed counter. In general, this instrument has a counting mechanism which is connected to the driven member automatically for a given period of time, usually one second. During this time, the counting mechanism makes a count of speed, and then it is disengaged from the drive mechanism, and allowed to return to zero position. An indicating mechanism registers this speed and the pointer remains stationary while the counting mechanism is returned to zero.

The writer will confine himself to the description of the Van Sicklen chronometric tachometer. Parts of this instrument are illustrated in Figs. 1 to 5; the assembled instrument is not shown, but the dial is simply uniformly graduated from zero to 2500 r.p.m. for a complete rotation of the pointer. Fig. 1 shows the assembled mechanism without case and dial.

A portion of the drive mechanism of the Van Sicklen tachometer is indicated by *A* in Fig. 1 and also in Fig. 2. *A* in Fig. 2 is the driving tang which is connected to the rotating shaft whose speed is to be measured. *E* is a worm fixed to the upper end of *A*, *A* and *E* rotate as a unit in a sleeve which is forced into the threaded boss of the tachometer case. A ball thrust bearing takes care of the end thrust caused by the action of the worm while a phosphor bronze sleeve serves as a guide bearing.

Part *C* (Fig. 2) consists of two gears mounted on a pivoted plate one of which has a crimped spring washer under it to

Fig. 2. Driving Mechanism Assembled on Bottom Plate

create friction; as *A* turns, gears on *C* turn through the medium of the idler unit *B*. A clockwise rotation of *B* causes the pivoted plate *C* to turn in an anti-clockwise direction. On account of the torque required to overcome the friction this action causes the right hand gear of *C* to be thrown into mesh with lower gear of the spring barrel unit shown in Fig. 3, which rotates in ball bearing *B* (Fig. 2).

Should there be a reversal of direction of rotation of driving tang *A* (Fig. 2) with a consequent reversal of *B* the pivoted

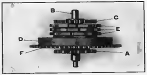

Fig. 3. Power Plant

plate *C* would turn in clockwise direction and throw the left hand gear of *C* into mesh with lower gear of the spring barrel unit. It will be seen that through the action of reverse unit *C* (Fig. 2), the gear *A* in Fig. 3 will rotate in the same direction the driving tang. *D* is the spring barrel and contains a coiled main spring similar to that of a watch.

In Fig. 3 gear *A* is fixed to shaft *B* and so is gear *C*; the spring is fastened to the shaft while the outer end bears against a polished ring, the whole chamber being filled with special grease. As the shaft *B* rotates, it winds up the spring until the torque overcomes the friction between the end of the spring and the polished ring, and then the end of the spring starts to slip. The spring is therefore kept wound up to constant tension by power

The spring barrel D furnishes the power for driving the watch unit C (Fig. 1), through gear F and intermediate gearing just as in an ordinary watch. The complete watch mechanism is shown in Fig 4. F is a temperature compensated balance and through escape mechanism similar to that used on regular watches allows the fly B, which has two arms, to escape a pinion C every half second. The friction disc D rotates by friction with B and is used as a shock absorber to prevent sharp blows upon the watch escapement and also to do away with rebound

Gear A (Fig 4) turns with fly B and through intermediate gearing allows spring barrel B (Fig 1) to unwind through a short arc every half second. Cams E (Fig. 3) are fixed to spring barrel and turn with it every half second.

By referring to Fig 1 it will be seen that the gear indicated by center arrow B is in mesh with the top gear of the spring barrel unit. Directly under this gear and fastened to it is a small V-tooth gear. This gear rotates at a speed which is directly proportional to that of the driving tang since it is connected through a train of gears, this gear is mounted on a lever which is acted upon by a spring. The lower end of the lever bears against the middle cam Fig 3 which causes it to rise and fall intermittently

When the lever is down the small V-tooth gear is in mesh with the center gear Fig 1, called the counting gear. The center cam allows the small gear to be in mesh for exactly one second during which time the counting gear is turned at a rate proportional to the speed of the drive. At the end of one second the small gear is thrown out of mesh for one second then it is allowed to be thrown into mesh again, so that the counting gear gives a new counting of speed every alternate second

In Fig 5 C is a counting gear with stop pin F which engages a flat strip H free to turn about the center of the unit. This arm in turn engages stop pin G on a ratchet gear E so that as the counting gear turns the ratchet gear, E is turned also. E is fastened to the center staff which carries the pointer

A locking lever which holds the ratchet gear in place is lifted for a short interval by the lower cam E (Fig 3), once during each cycle of operation. During a complete cycle of operation involving four movements of the fly or a period of two seconds, the following actions take place: the small gear is thrown into mesh with the counting gear for one second, the pointer is brought up to a position which indicates the average speed during that second, the small gear is then thrown out of mesh and at the same time a locking lever drops into place and holds the counting gear in its advanced position, at the same time the locking lever on the ratchet gear is released so that the latter can drop back through the action of its spring to register reduced speed. If there should be a reduction in speed between one cycle of operation and the next, the upper locking lever holding the counting gear is then released by the action of the top cam, Fig 3, and a spring returns the counting gear to its zero point. During the next cycle the counting gear gives a new count of speed and the hand is allowed to accommodate itself to the new position and to hold it while the counting gear returns for the new cycle. The hand of the instrument is accordingly reset every two seconds and registers average speed over one second.

It will be seen from an analysis of these operations that the instrument is strictly mechanical in its principle and that its calibration is controlled by the timing of the watch. In the Van Sicklen instrument the watch used is unaffected by temperature variation on account of its complicated balance. The following results were obtained by the Bureau of Standards at Washington, D. C., upon the average of all of the production samples submitted

The maximum calibration error based on a full scale reading, was about .3 of 1 per cent. The change caused by 150 hr of vibration and running was about .2 of 1 per cent, while the greatest temperature error, range of temperature from + 40 deg Cent to — 10 deg. Cent. was a little over .1 of 1 per cent. Inasmuch as this instrument is readable to the nearest 10 r p m it will be seen that the errors are less than the smallest division that can be read on the tachometer

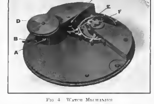

Fig 4 Watch Mechanism

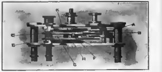

Fig 5. Counting Mechanism

New Passenger Zeppelin

A new Zeppelin airship, named *Bodensee*, on its maiden trip from Friedrichshafen to Berlin, attained a maximum speed of 75 miles an hour

The builders of the new type of machine have discarded the familiar cigar shape of the old Zeppelins and adopted a streamline hull shape

The *Bodensee* is 120 meters long and accommodates thirty five passengers. It is equipped with wireless telegraphy and has a spacious passenger cabin. The passengers are able to obtain running hot and cold water. The aircraft is to go into a daily service

British Seek Mail Data

That the American aerial mail service is attracting international attention is indicated by the receipt of a letter from Winston Spencer Churchill, British Air Minister, to John A Jordan, superintendent of the Cleveland-Chicago air mail division, in which he seeks all possible data on the system. The letter has been forwarded to Washington.

Mr. Churchill's letters bring data on British air systems and says Great Britain is seeking every possible method to improve and develop aerial travel.

New Air Routes

The Curtiss Aeroplane and Motor Corp has announced plans for three air routes for passenger service. They will be to Rochester, Syracuse, Utica and Albany, to Erie and Pittsburgh, Pa, and across the Canadian border to Hamilton and Toronto. The State route will be opened this fall, but the other two probably will not be in operation until spring

Prediction of Airplane Performance

By I. M. Laddon
Aeronautical Engineer, U. S. Air Service

The following method of estimating airplane performance was outlined to the author by Lieutenant Alkan of the French Aviation Mission. It consists in comparing the airplane whose performance is to be found with the actual performance of an airplane of similar type on a power and a surface loading basis.

The actual performances of three different types of airplanes are given on the chart. These airplanes are all good, clean designs, therefore, when comparing an airplane that is poor aerodynamically with any one of the above, an allowance should be made in the high speed obtained. In extreme cases this allowance may run as high as 10 m.p.h., but for all ordinary designs no allowance need be made. The ceiling is not correspondingly affected. Curves of actual performance shown include the three common types: (a) Single-place scout. (b) Two-place fighter or reconnaissance airplane. (c) Three or four-place, twin-engined bomber. By selecting the proper type for comparison one can make an accurate prediction.

It has been the author's experience that the results obtained through this simple method are much more reliable than those given by the old laborious method of computing the parasite resistance, horsepower required, available, etc. It should prove quite useful to the designer, since it affords a rapid and accurate means of estimating how changes in weight, surface or horsepower affect the performance of the plane in question

Example—Twin engined airplane: weight, 7200 lb.; horsepower, 800; surface, 900 sq. ft.

The obvious plane to use for comparison is the twin-engined bomber

1. Find the intersection on reference line B of a straight line through the propeller efficiency and horsepower

2. Join this point to the surface and note the intersection on line V.

3. Find the intersection on reference line C of a straight line through weight and surface

4. Join point on reference line C to point on reference line B, and note intersection on line A.

The linear difference between the points found on lines A and V and the corresponding points given for the plane which it is being compared with are the measures of the relative ceiling and speed

5. Construct a curve similar to curve C, using ordinates increased (or decreased) by the difference in altitude (C-K) and abscissae increased (or decreased) by the difference in speed (C-K)

6. From the point of absolute ceiling (E) draw curve parallel to curve D.

This curve gives the minimum speed for horizontal flight at given altitudes, while the curve first constructed gives the high speed. The enclosed area is the speed range.

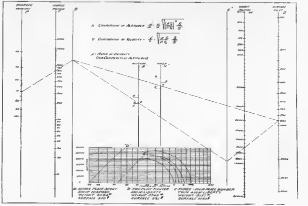

Chart for Estimating Airplane Performance

Reducing Shrinkage and Swelling in Laminated Wood Construction

By J. S. Mathewson

Engineer in Forest Products, U. S Forest Products Laboratory

One of the results of the enormous and unprecedented demand upon our timber resources during the war was the development of new methods of utilizing more efficiently the available supply of timber, among them the development of the use of small pieces of wood glued together and then machined or cut to any form. It is the purpose of this article to discuss briefly a number of the more important factors which relate to the wood itself and upon which the satisfactory use of wood in laminated construction largely depends. Gluing is not considered It may be stated incidentally, however, that numerous experiments on the gluing of various species have been made at the Forest Products Laboratory of the U S Forest Service at Madison, Wis., and have afforded information which has been used as a basis for formulating specifications for the successful use of glue

Besides the stresses in laminated construction, such as an airplane propeller, strut or wing beam, due to external forces, other stresses, called internal stresses, exist which are due to forces acting between or within the laminations. In some cases they may be of sufficient magnitude to cause serious weakening, and may independently, or in combination with stresses due to external force, result in failure of the structural member The great importance of this fact is indicated by the very large percentage of propellers which have been rejected as a result of the effect of internal stresses.

Some Shrinkage Characteristics of Wood

If a stick of green timber is dried gradually it will retain the same dimensions until the moisture content of some part of it reaches the fiber saturation point, which for most species corresponds to a moisture content of between 20 and 30 per cent, based on the oven-dry weight of the wood As the drying continues below this point, however, the moisture begins to leave the cell walls and shrinkage ensues.

Investigation has shown that for most species the shrinkage around the tree, or in a tangential direction, is much greater than that from the center toward the circumference, or in a radial direction. The width of a plain or flat-sawn board is in the circumferential direction, while that of a quarter-sawn is in the radial direction For a given change in moisture content, the shrinkage in the width of a quarter-sawn board averages about 0 6 as great as that of a plain-sawn In general, the shrinkage parallel to the axis of the tree is negligible

Shrinkage is closely related to the density of wood, dry wood when exposed to very moist air absorbs moisture and swells. Conversely, wood dried to practically constant condition in a normally dry climate, if exposed to exceptionally dry conditions loses more moisture and shrinks Two pieces of wood of a given species when exposed continuously to the same conditions of temperature and humidity will ultimately come to practically the same (within about 1 per cent) moisture content, irrespective of their relative moisture contents when first exposed to such conditions.

Quarter sawn and plain-sawn boards differ in their rate of drying, and even individual pieces cut from a tree in the same manner differ in this respect. Not only do dense pieces shrink more than light pieces, but they also dry more slowly. Position in the pile in air seasoning or in a kiln or drying chamber, of course, has a large influence on rate of drying

Possible Effect of Shrinking on Laminated Construction

Suppose a flat-sawn board be glued between two quarter-sawn boards all having the same moisture content. Under subsequent changes of moisture content the flat-sawn board will, as noted above, tend to shrink or swell more than the quarter-sawn boards This difference will set up a shearing stress in the glued joint As a result the glued joint may give way entirely, it may partially hold, or it may hold perfectly In either of the latter cases the center piece will be under stress in tension across the grain and, consequently, under tendency to split. This tendency may become localized and result in a weakening of the wood fibers, the effect of which may be visible or invisible From these considerations it is evident that better results would be secured by having all the laminations either plain-sawn or quarter-sawn, so that the difference between the shrinkages of adjacent laminations would be reduced to a minimum. In general, still better results would be obtained by the use of quarter-sawn boards, since they shrink considerably less than flat-sawn boards, quarter-sawn boards also dry less rapidly This characteristic would tend to cause additional stresses in a glued joint between quarter-sawn and flat-sawn laminations.

Again, if the several laminations differ in moisture content or in density these factors may affect to a marked degree the relative shrinkage of the laminations, and consequently the strength of the glued joint.

It is possible, moreover, that the conditions cited in the two preceding paragraphs may exist in combination and further complicate the difficulty of securing satisfactory construction. For instance, suppose that a propeller consists of alternate laminations of flat-sawn, quite dense boards at a relatively high moisture content glued up with boards which are quarter-sawn, less dense, and at a much lower moisture content when glued The tendency of the flat-sawn laminations to shrink or swell with subsequent changes of moisture content will be very much greater than that of the others, with the result that internal stresses of considerable magnitude will be developed. It is apparent, therefore, that these internal stresses may combine with the stresses from external causes to produce failure under smaller external load than would be the case if more care were taken during the manufacturing process.

Moisture Content Same as in Service

It is very desirable not only to have the moisture content of the individual laminations the same at the time of gluing, but also to have it approximate that to which it will ultimately tend to come in service. For example, a propeller to be used in a hot, dry climate, such as that of the Mexican border, should be constructed of laminations having a lower moisture content than one to be used in a more humid climate such as that of Flanders.

Hints for the Manufacturer

It is worth while now to consider how the manufacturer can satisfy some of the conditions necessary for successful manufacture involving laminated construction.

Quarter-sawn material usually includes boards in which the angle made with the radial surface by the annual growth rings (as shown in a cross section) is 45 deg or more. In case the manufacturer's stock consists of mixed flat-sawn and quarter-sawn boards, an improvement will be made if these boards are divided into three groups—quarter-sawn, flat-sawn and intermediate. A structural member could then be made entirely from boards of one group, which would minimize one source of difficulty Further, a subdivision of the boards into separate groups according to their densities is advisable in order to prevent the use of boards in the same member if they differ considerably in density

In order to obviate, as far as may be possible, troubles arising from differences in moisture content, it is very desirable that after the boards have been kiln dried they be stored under proper conditions of temperature and humidity for a sufficient length of time to permit them all to come to the same moisture content before gluing This will minimize the moisture changes during and subsequent to manufacture

An additional storage after gluing and before the first roughing-out is advantageous in that it allows the moisture introduced with the glue to be uniformly distributed throughout the laminations

In many cases the deleterious effect of internal stresses may be minimized by using quarter-sawn material graded according to density or dry weight and having a moisture content approximating that to which it will eventually come in service.

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